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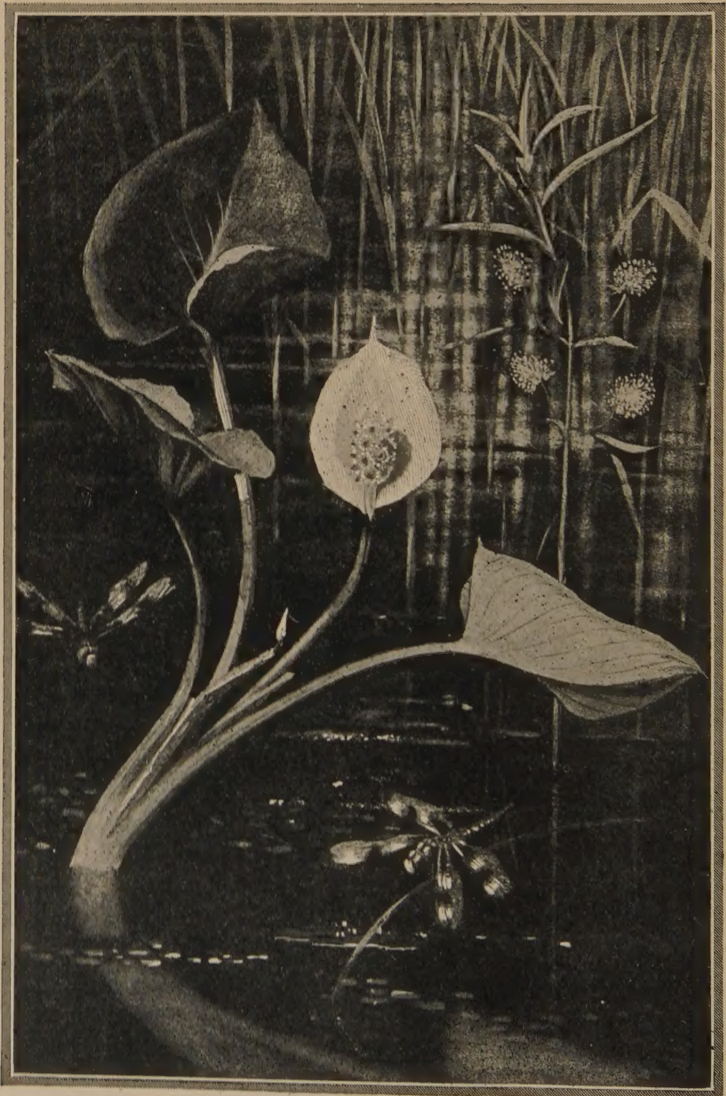

The pond of the marsh calla

After a water colour painting by Robert Holmes, R.C.A.

BOTANY
FOR HIGH SCHOOLS

BY

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PREFACE

This book has been written to cover the Lower School Course in Botany, as outlined in the regulations of the Ontario Department of Education.

As the study of Botany is commenced in the fall, the topics suitable for that season have been placed at the beginning of the book, and are followed by those that can be taken up to best advantage in the winter and spring. In this way the work is presented in the text in the same order as in the syllabus of the Department of Education.

In preparing this text the aim of the authors has been to make the study of the plant world interesting to the beginner. Therefore, as function is more interesting than structure, the study of the latter has been introduced always with the purpose of explaining the former.

The appendix is for reference, and the terms in it should be given to the pupils only after they have seen them exemplified in plants.

Thanks are extended to all who have assisted in the preparation of this text, and more particularly to Professor J. H. Faull, who read the proof of the chapter on Fungi.

Toronto, 1928.

SUGGESTIONS FOR THE TEACHING OF FIELD BOTANY

This department of botany is concerned with observations made on plants in their natural habitats.

While the teacher cannot directly supervise this work, he should make some effort to have his pupils "carry on" in the field themselves. With this object in view different plans may be adopted.

An appeal may be made to the inherent desire to classify. Almost invariably the first question that a person asks about a flower is—"What is its name?" Wishing to know the name of the plant, the majority of pupils will take a genuine pleasure in classifying it, and will find, perhaps to their surprise, that the successful keying of a plant gives a feeling of satisfaction akin to that experienced when a mathematical problem is solved correctly. There is no reason why the pupils should not enjoy the identification of flowers as much as they do that of birds.

In the naming of the specimens which he has found, the pupil should, as soon as possible, be made independent of the teacher. It is doubtful if any but common names should be used in the junior grades, but work with the "key" must be introduced early, as soon as a very few type plants have been described. Of course, terms often occur with which the pupil is not familiar, but for the meaning of these he can consult the teacher or the appendix.

It is an excellent idea to encourage the pupils to keep a list of the plants which they have classified. In their search for "new" specimens they will unconsciously absorb a great deal of information about plants in general. There are many field botanists who, though they have read very little on the subject, are rich in the lore of fields and woods.

If a teacher, in his busy life, can find time for a field day with his pupils, it will have a good effect upon all his relations with them. The study of plants in the field will prove most enjoyable to teacher and pupils, and the social intercourse which it affords will form a bond of mutual understanding between them. A field day, also, presents excellent opportunities to demonstrate the need of care in the conservation of our wild flowers. Many of the flowers, such as certain gentians and the trailing arbutus, are becoming alarmingly rare, especially near the large centres of population. The pupils can soon be led to see how harmful it is to pluck many of our rare flowers, and how useless, since they commence to wilt almost as soon as they are plucked.

Other methods of approaching field work will suggest themselves to the teacher. Any plan is good that takes the pupil into the fields and woods, not on aimless walks, but with a botanical purpose. The collecting of leaves and twigs has often produced good results.

Class discussions, which need not last longer than fifteen minutes, are helpful. Occasionally the teacher may show some interesting specimen, preferably one given him by a pupil. Such material may often be brought in by the pupils, if the teacher encourages them thus to make discoveries for themselves.

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BOTANY

CHAPTER I

INTRODUCTION

To the beginner, botany is an interesting study, for it arouses a sense of wonder and appeals to the natural desire to know about living things.

What could be more fascinating, for example, than to watch the flowering of the garden evening primrose during the hour of dusk! The buds of this plant, for some minutes, seem as though quivering with a pent-up energy. Suddenly they burst into flowers of gold, like brilliant flames against the dark green foliage, and are still visible at some distance long after dark. Or what more astonishing than to observe the extent to which certain plants provide for the continuance of their species in their own or in neighbouring localities! The number of seeds produced by an average-sized plant of the sweet alyssum, for example, has been shown to be above 25,000, and in many of our common weeds this number is greatly exceeded. One wonders what the effect on nature would be if each seed produced by every such plant were to germinate and grow undisturbed.

Only to look about during the season of abundant growth and to try to estimate the number of colours displayed in plants helps one to realize how inexhaustible are the resources of nature. Greens, reds, blues, yellows, whites, and even blacks here and there meet the eye, and yet in this great riot of colour there is not a single clash. Still more striking is the appeal which these different colours make, not only to the artistic sense of man, but to the various insects and other animals. It is said that the favourite colour of the honey-bee is a deep violet, while it is indifferent toward green and seems to avoid and even to dislike red. An eminent botanist once observed two species of bergamot, one with blue flowers, the other with scarlet, growing side by side in the same bed in a well-known botanic garden. About the blue flowers the bees and the butterflies hovered in large numbers, but the scarlet flowers were avoided.

Plants resemble animals very closely in their life functions. Both plants and animals must be supplied with oxygen in order to live. In the case of plants it is taken in by the leaves, which play the same part in this process as the lungs of the animal. Plants, like animals, must have suitable nourishment. In the preparation of food, green plants have this advantage, that they can manufacture it from simple materials obtained from the atmosphere and the soil. This no animal is able to do. The pitcher plants and the sundews are particularly animal-like in habit, since they have learned to catch their prey and feed upon it.

There is a mechanism in some plants that, in its action, recalls the nervous system of animals. When one part of the sensitive plant is touched, other parts of the plant will respond by movement. If an insect alights on the leaf of a sundew, not only the hairs touched by the insect, but other hairs, also, aid in the capture of the visitor.

Why do trees planted close together grow tall and slender? Why do the roots of trees fill up wells and ditches in their neighbourhood? The health of plants is just as dependent as that of animals upon a sufficient supply of light and water, and plants will always grow in the right direction to secure these necessities of life. Some plants even set their leaves so as to secure just the proper amount of light. The common prickly lettuce resembles the compass plant in exposing more leaf surface to sunlight from the east and west than from the north and south. The light is not so strong from the east and west, and to compensate for this it falls on a larger leaf area.

The knowledge gained by the study of botany has played a very important part in our modern life. Both our comfort and our happiness depend to a great extent upon certain valuable plant products and upon their utilization to the best advantage by the aid of the trained botanist. The management of our forests is being placed more and more in the hands of experts, by the advice of whom the cuttings and other operations in the woods are being carried out. The old forests are being cut in a scientific way, and a beginning has been made in the reforestation of cleared areas by the scientific planting of young stock. It seems only a question of time until the dream of the foresters will be realized, and crops of timber will be cut as we now cut crops of grain. By scientific selection and the crossing of different varieties, our grains and other food plants have been greatly improved. By similar methods Luther Burbank has demonstrated to the world how flowers of almost any colour and shape may be produced at will. The scientific treatment of plant products has enabled Great Britain to gain a world supremacy in rubber in the last few years, by planting large areas in the Malay States and Ceylon with the seedlings of rubber plants grown in the Kew Gardens in London.

Botany is the science of the study of all that pertains to plants. The term as used by botanists includes the study of:

1. The forms and the structures of the various parts of plants.

2. The relations and the functions of the tissues of which they are composed.

3. The manner in which each plant carries on its work, thus fulfilling its place in nature.
4. The methods by which plants reproduce or multiply in numbers.
5. The classification of plants into groups or families.

The study of botany furnishes many examples of the work accomplished by living plants and shows how their activities are associated with other forms of life.

CHAPTER II

FLOWERS—THE PARTS AND THEIR USES

THE PLANT AS A WHOLE

The parts of a flower.—The tall buttercup is a very suitable plant with which to commence our practical study of botany. If this species, however, cannot be obtained, another common flowering plant will do almost equally well.

As you know, a plant consists of four main parts—*roots*, *stem*, *leaves*, and *flowers*. While the other parts of the plant are very important, the flowers attract our attention, and in them we are most interested.

The flower of a buttercup may be taken as a type in which all the parts are present. On the outside of a flower are to be found five small, spreading, leaf-like bodies. Each of these is known as a *sepal*, and all of them together form the *calyx*. The calyx in this flower is somewhat yellowish, but in most flowers it is green. If the flower which you are examining has been open for some time, one or more of the sepals may have fallen off.

Inside the circle of sepals is a second *whorl* of bright yellow leaves; to each of them the name *petal* is applied, and together they are known as the *corolla*.

There are two parts of the flower still remaining. Nearer the outside are a number of small bodies covered with a yellow material; each of these is supported on a very slender stalk. These stalked bodies are the *stamens*. (See Figure 1.)

There still remains at the centre of the flower a somewhat rounded mass of small, seed-like bodies, each of which is known as a *carpel*. Together these form the *pistil* (Fig. 5).

This last part of the flower can be seen better in a flower from which some or all of the other parts have dropped off.

It is interesting to examine other flowers, such as those of the nasturtium, butter and eggs, bouncing bet, or petunia, and look for the parts which we have found in the buttercup.

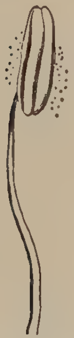

Fig. 1. A stamen, showing the filament and the anther. Give a reason for considering this stamen mature.

In our practical study of plants, a needle inserted into a wooden handle, and a small lens are absolutely essential.

The uses of the parts of a flower.—The chief parts of a flower, as we have seen, are: the calyx, the corolla, the stamens, and the pistil.

Each of these parts named above is of special use to the plant. The calyx — the outer whorl of floral leaves — protects the inner parts from injury. The corolla assists in this, acting as a second line of defence, since its petals stand opposite the lines of contact of the sepals.

The corolla has also the much more important function of attracting insects, especially bees, wasps, and butterflies. We shall see later how essential the visits of such insects are to the flowers. Have you noticed how their colours are suited to make the corolla conspicuous? They are usually white or yellow when they are against the background of the plant's foliage, but blue or red when raised above it. If a calyx is brightly coloured, it also aids in attracting insects to the flower.

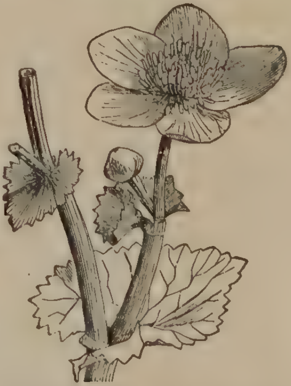

Fig. 2. Marsh marigold. What additional use does the yellow colour give to the calyx of this plant?

Nectaries.—From the so-called *nectaries* of flowers there oozes out a sweet liquid (*nectar*), upon which many insects feed. It is the lure of this delicacy that induces them to visit the flowers. These organs are found especially useful to bees, since they gather the nectar and manufacture their honey from them. At the base of each petal of the buttercup there is a small bracket-like nectary that can easily be seen with the aid of a lens. The tips of the spurs of many flowers, such as the columbine (Fig. 3), are examples of nectaries.

The stamens and pistil are known as the essential organs of the flower, since seed cannot be produced without them. From the former the *pollen* escapes, and in the carpels of the latter the *seeds* are formed.

What is a flower?—Flowers are so plentiful and we are so familiar with them that at first glance it would not seem difficult to name their common characteristics or to state what a flower is. Recalling the chrysanthemums, gladioli, orchids, asters, etc., that ornament our gardens and woodlands, some might say that flowers are always brightly coloured. Many flowers, however, differ in colour very little from the ordinary foliage of the plants. For example, from their colour alone the grass and sedge flowers would not be recognized as flowers. Others might say that fragrant odours are a distinguishing feature of all flowers. But, while many flowers are fragrant, some are odourless.

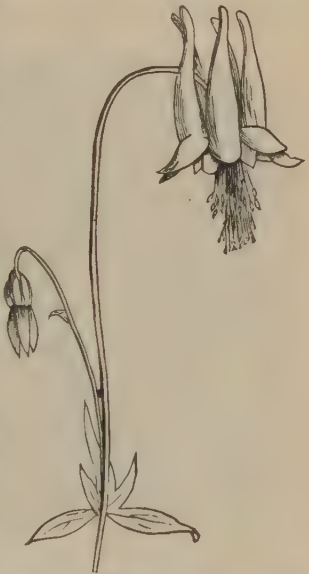
Fig. 3. Wild columbine. Watch carefully the insects that visit the columbine flowers.

and others are actually ill-scented. The odours of the purple trillium and the carrion flower, for example, are not pleasant. Flowers differ not only in colour and odour but also in shape and size. In size they vary from the truly giant flower, the tropical rafflesia (Fig. 4), which has a blossom more than three feet in diameter, to one of our own tiny water plants, wolffia, which is a mere speck. These smallest of flowering plants may be found often as minute green grains on the water of ponds.

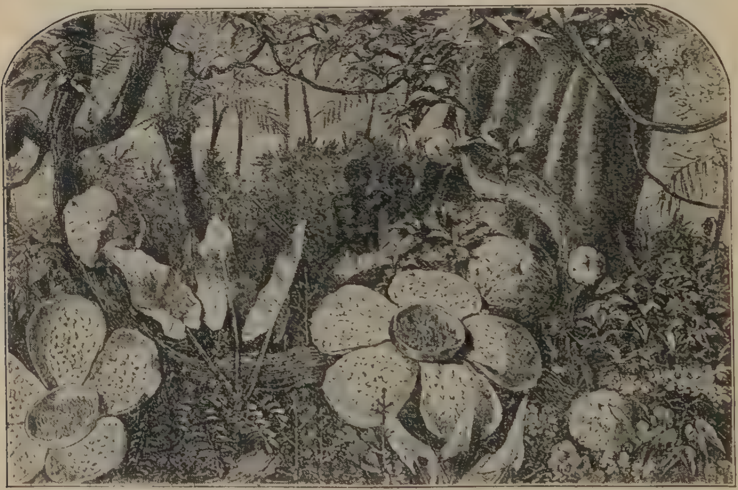

Fig. 4. Rafflesia, a giant flower of the Tropics. What wild plants do you know that have large blossoms?

From appearance alone, then, it would be very difficult to give type characteristics that are possessed by all flowers. From the standpoint of its use to the plant, however, a flower may be described as any of the parts of a plant that assist more or less directly in the production of a seed-containing fruit. The term flower, therefore, includes structures such as the cones of the pine, which are not flower-like but are essential to seed production, and excludes certain other structures, such as brightly coloured species of fungi, that might easily be mistaken for flowers but should not be classed as such because they do not aid in producing seed.

Practical Questions and Suggestions for Outdoor Work

1. Where is nectar stored in the flowers of the following plants: Clover, butter and eggs, and nasturtium?

2. What advantage to the plant is gained by the grouping of small flowers into clusters?

3. Make a list in your note-book, with dates, of all wild plants in your locality that you have found blooming in September.

4. Name three plants the flowers of which close on dull days.

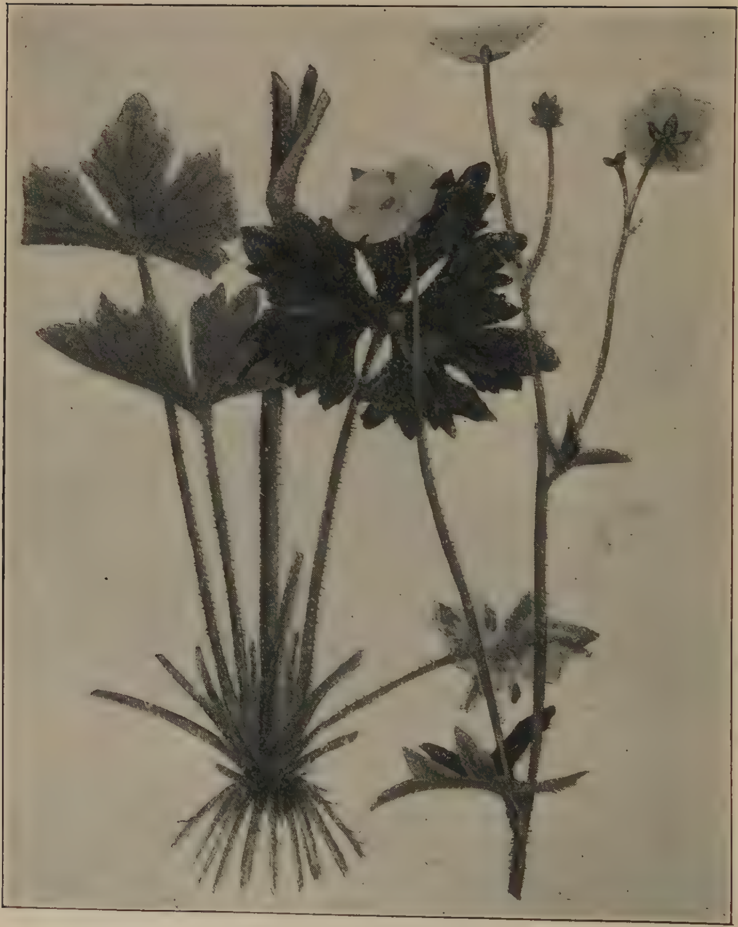

Fig. 5. The tall buttercup

CHAPTER III

STUDY OF THE TALL BUTTERCUP

(*Ranunculus acris*)*

The tall buttercup is a well-known plant of the wayside and the damp meadow. It is very attractive, with its dark green foliage and butter-coloured flowers. Many people, especially farmers, regard it as a poisonous weed. Cattle avoid eating it, but their dislike of it may be due to its acrid or sharp, disagreeable taste.

Like many others of our troublesome weeds, this plant is an immigrant from Europe. Since it is now found throughout Canada, it must have been very successful in establishing colonies.

Although in some instances this plant may mature in one season, in the majority of cases it requires two or more years for seeds to produce plants with flowers and seed. Plants that grow year after year from the same root system are called *perennials.*

Like the majority of plants, the tall buttercup consists of the following parts: (1) flowers, (2) stem, (3) leaves, and (4) root.

Flowers.—Each flower is composed of several parts: (1) calyx, (2) corolla, (3) stamens, (4) pistil. These are attached to the more or less swollen end of the flower stalk, called the *receptacle.*

The calyx, which forms the lowest or outermost circle of the flower, consists usually of five small, leaf-like pieces known as sepals. These are greenish, and as they are not united to one another the calyx is *polysepalous*. Since it is attached to the receptacle below and free from the pistil, it is also *inferior*. (See Figure 191.)

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* In this case and in that of the plants in the following three Chapters, it is suggested that, if more convenient, any other plant from each group mentioned may be selected for study.

The circle next to the calyx is the corolla; it also usually consists of five parts known as petals. These are bright yellow in colour. They are leaf-like, but much longer than the sepals. Since the petals are free from one another, the corolla is *polypetalous*. Like the calyx, it is attached to the receptacle and free from the other whorls of the flower; hence it is said to be *hypogynous* (Fig. 191). The calyx and the corolla, taken together, sometimes receive the name *perianth*.

Inside the corolla are many stalked bodies, the stamens. Since they are more than ten in number, they are said to be *indefinite* or *numerous*. Each stamen consists of a yellowish, two-lobed case, termed the *anther*, which is supported on a tiny stalk, the *filament*. The filaments in this flower are all of the same length. Since the stamens are numerous and separate from one another, they are said to be *polyandrous*. Like the petals, the stamens arise from the receptacle and are hypogynous.

In the centre of the flower is found the remaining part, the pistil. It is composed of numerous roundish bodies each of which tapers to a bent point. These parts of the pistil are known as carpels. A pistil may consist of one or more carpels. The swollen base of each carpel is called the *ovary*. The small point is the *stigma*, and the very short stalk which connects it with the ovary is the *style*. Since the carpels are not at all connected with one another, the pistil is said to be *apocarpous*. As the ovaries are free from and above the calyx, they are *superior*. (See Figure 191.)

This type of flower is known as hypogynous.

When a flower is in seed, each carpel is changed to a one-seeded fruit. If one of these is cut across and examined with a lens, the seed will be found not to fill the whole of the ovary. Such a fruit is called an *achene*. (See Figure 35.)

Stem.—The erect branching stem is cylindrical and from two to three feet in height. It is more or less hairy.

Leaves.—Some of these spring from the stem at the ground level or below it, the others from the stem above the ground. The former are called *radical* leaves, the latter *cauline*. Both are *stalked* or *petioled*. The blade of each leaf is divided to the main vein or *midrib* into three parts, and each of these is again cut into three divisions, but not to the midrib. These parts are lobed into narrow divisions. The petioles are flattened or inflated where they join the stem.

Root.—The root is made up of many branches, none of which is distinctly larger than the others. This type of root is called a *fibrous* root.

Classification.—The tall buttercup belongs to a large family of plants known as the *Crowfoot Family* or *Ranunculaceae*. *Ranunculaceae* comes from a Latin word which means a little frog. It is applied to these plants because there are among them aquatic species that are found where frogs are abundant. Besides several species of buttercups, this family also includes such well-known plants as marsh marigold, clematis, hepatica, columbine, and larkspur. Plants belonging to this family will be found to have the following characteristics in common, while in other respects they may differ very widely:

1. The whorls of floral leaves—the calyx, corolla, stamens, and pistil—are not united to one another.
2. The members of each whorl—the sepals, petals, stamens, and carpels—are also entirely distinct.
3. The stamens are numerous.

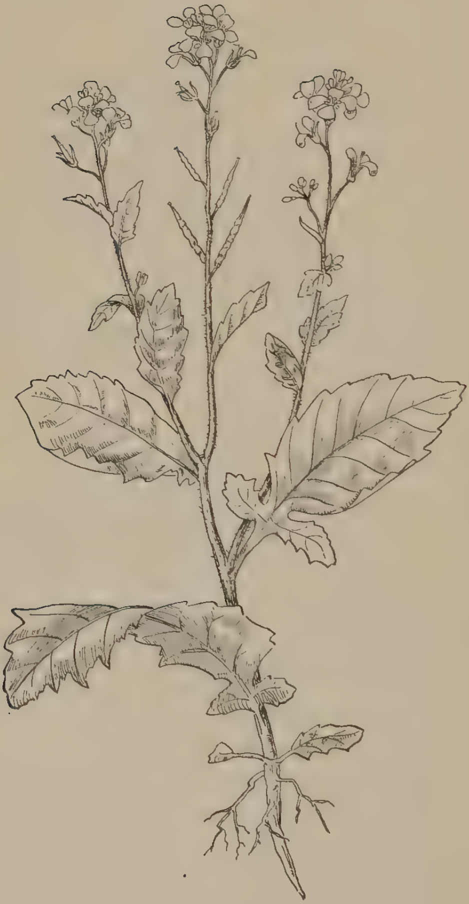

Fig. 6. Wild mustard

CHAPTER IV

STUDY OF THE WILD MUSTARD OR CHARLOCK

(*Brassica Arvensis*)

The wild mustard, which has been introduced from Europe, is now a common weed throughout Canada. It occurs in waste places and, unfortunately, too frequently in farm crops, where it often makes the whole field literally yellow.

Because this plant completes its growth, producing its flowers and seeds, in one season, it is called an *annual.*

Flowers.—These are supported on small stems or *pedicels* attached along common stalks. This method of arrangement of the flowers forms elongated clusters, known as *racemes* (Fig. 206.) As in the buttercup, each flower is composed of several parts: (1) calyx, (2) corolla, (3) stamens, and (4) pistil. These are attached to the receptacle.

The calyx, which consists of four sepals, is polysepalous and inferior.

The corolla consists of four yellow petals. These are arranged in the form of a cross. They are leaf-like but larger than the sepals, and, since they are not united, the corolla is polypetalous. The corolla, like that of the buttercup, is attached to the receptacle and free from the other whorls of the flower; hence it is hypogynous.

Inside the corolla are six stamens. Each one of these consists of a filament and an anther, as in the buttercup. The filaments are not all of the same length; four are long, and two are short; hence the stamens are *tetradynamous.* It will also be noticed that the two short stamens are inserted farther out from the centre of the flower than the other four. (See Figure 7.) In this plant, also, the stamens are hypogynous.

In the centre of the flower is found the remaining part, the pistil. It is composed of a vertical, elongated, greenish body, the ovary. This tapers into a short stalk, the style, terminated by a rounded head, called the stigma. If the ovary is cut across the middle and examined with a lens, it is seen to consist of two chambers, and, in consequence, the pistil is considered to be composed of two carpels, fused or grown together. The union of the carpels of the pistil is indicated by the term *syncarpous*. The ovary resembles that of the buttercup in being free from and above the calyx, and is, therefore, said to be superior.

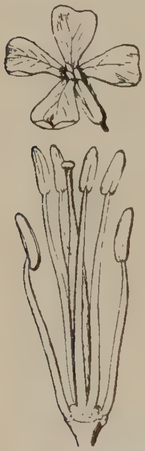

Fig. 7. Above is shown the cross-shaped corolla of the mustard; below, the tetradynamous stamens of the mustard.

This type of flower is known as hypogynous.

If the older flowers are examined, the pistil will be found much enlarged to form a long, knotty pod, terminated by a two-edged *beak*. The seeds in this fruit are attached to the edges of a thin partition that runs lengthwise of the pod, dividing it into two compartments. To such an elongated fruit the term *silique* is applied. (See Figure 32.)

Stem.—The usually branching stem grows erect to a height of from one to three feet. It is roughened with stiff hairs, many of which are deflexed as they point downward on the stem.

Leaves.—Some of the leaves spring from the stem at the ground level or below it, the others from the stem above the ground. The former, the radical leaves, are stalked or petioled; the latter, the cauline, are *sessile* or nearly so, as their petioles are altogether or almost wanting. The root leaves are deeply lobed, the terminal lobe being the largest; the stem leaves are similar to these or merely deeply toothed. All the leaves are *pinnately net-veined*; that is, down the centre is a main vein or midrib from which smaller veins are given off on each side.

Root.—If the soil is carefully removed from the roots of the plant, there is found to be a main axis, from the sides of which smaller branches are given off. This type of root is called a *tap* root.

Classification.—The wild mustard is typical of a large family of plants known as the *Cress Family* or *Cruciferae.* Many common plants belong to this family. In addition to other forms of mustard, it also includes shepherd's purse, water cress, rock cress, etc., as well as sweet alyssum, candytuft, and the stocks of the gardens. All of these possess several similar family characteristics, such as:

1. The sepals and petals are each four.
2. The corolla has its petals arranged in a cross.
3. The stamens are usually six, four long and two short (tetradynamous).
4. The fruit is in most cases a long pod called a silique (long), or a short pod of the same type, called a *silicle* (short).

CHAPTER V

STUDY OF THE NEW ENGLAND ASTER

(*Aster Novae-Angliae*)

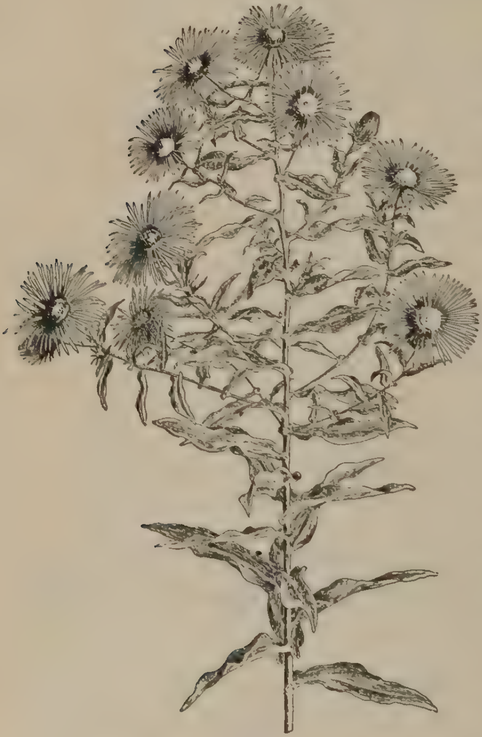

Fig. 8. The New England aster

This is one of our largest and handsomest native asters. It is plentiful in moist locations and is also popular in cultivation. It may be found more convenient, instead of the aster, to take up the sunflower.*

Flowers.—What may be mistaken in this plant for single flowers are in reality heads composed of many small flowers or *florets*. The stalks supporting these heads arise from different points on the branches of the stem, but reach approximately the same height. This arrangement is known as a *corymb* (Fig. 207). On examining a head, it will be found to be protected on the outside by a loose whorl of small, greenish leaves or *bracts*, forming an *involucre*. Around the inside of this are numerous narrow violet-purple leaves. The nature of these can be understood only if the head is cut through the centre lengthwise and the florets are separated with the aid of a needle. It will then be seen that there is a circle of florets around the head, and the purple leaves are their corollas. A lens will show that only one side of each of these is prolonged, the other remaining very short. All the florets inside this outer circle will be found to have corollas that are prolonged equally all around. The florets with the purple corollas are said to form the *ray* of the head, and the yellow florets in the centre the *disk*. (See Figure 10.)

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*The aster or sunflower should be compared with the dandelion or chicory (Fig. 9), and with the burdock or thistle.

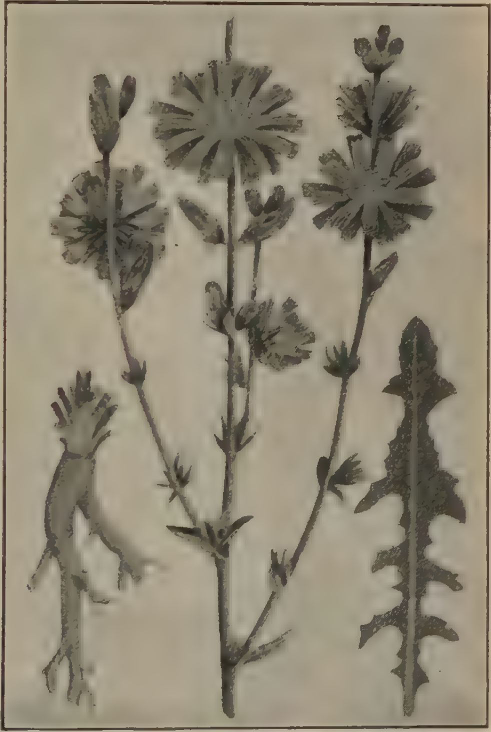


Fig. 9. Chicory. Compare the structure of the flower head of this plant with that of the aster.

The lens will be required to make out the details of the florets. Let us consider the disk floret first. (See Figure 11.)

Commencing with the corolla, which is the most conspicuous part, it can be easily seen from its five-toothed border that the petals are five in number united together. Because of this union of the petals, the corolla is said to be *gamopetalous* and, since it is attached to the ovary, *epigynous* (Fig. 199).

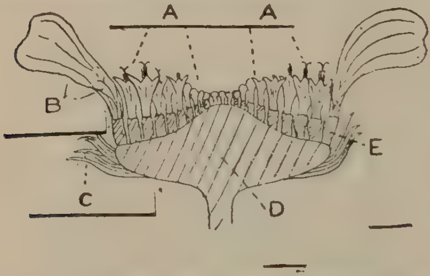


Fig. 10. A section of the head of a composite flower, such as the aster. A, A, disk flowers; B, ray flowers; C, bracts of the involucre; D, the receptacle; E, the ovary of a ray flower

The style with its two stigmas is easily seen protruding from the corolla. A careful examination with the lens will show an enlargement about the style. This is produced by the union of the anthers of the five stamens. If a needle is used to split the corolla tube, the five separate filaments which are attached to the interior of it (*epipetalous*) can be found. When the anthers are united around the style and the filaments are separate, the stamens are said to be *syngenesious* (Fig. 204).

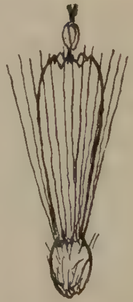


Fig. 11.—A disk flower of the New England aster

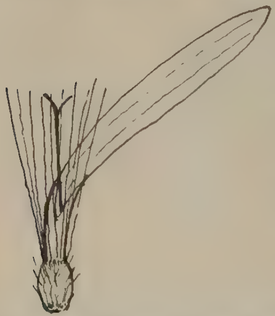


Fig. 12. A ray flower of the New England aster

The tiny tuft of hairs so apparent around each corolla is considered to represent the calyx. It is believed that this calyx is attached to the surface of the ovary, and, in consequence, its sepals must be united. This forms a superior and *gamosepalous* calyx (Fig. 11).

The ovary in a mature head will be found to contain only one seed, but from the two stigmas it is inferred that there are two carpels united, only one of which develops a seed. Because of this union of the carpels, the pistil is said to be syncarpous, and, as the ovary is united to the calyx, it is inferior.

An examination of a ray floret (Fig. 12) will show the same arrangement of the parts, except that the stamens are not developed.

The two shapes of the corolla are distinguished by two terms. The corolla of the disk floret, of equal length all around, is said to be *tubular*, while that of the ray floret, greatly prolonged on one side, is *strap-shaped* or *ligulate*.

Fig. 13. A New England aster in its natural surroundings

Stem.—The New England aster has a stem from two to five feet high, with branches at the top terminating in flower clusters. The stem is cylindrical, stout, hairy, and somewhat woody. A peculiarity about it is that it usually has a reddish-purple tinge.

Leaves.—The leaves are crowded on the stem. They are about three inches long and one-half inch wide; this and their sharp points cause them to be considered *lanceolate* in outline. (See Figure 239.) The leaves at the top of the stem, while smaller, are of much the same shape. All the leaves are attached by a clasping base with an ear-like lobe on each side of the stem (*auriculate*). (See Figure 250.) All are finely net-veined, with a prominent vein through the middle of the leaf from the apex to the base (pinnately net-veined). The margin is not indented in any way, that is, it is *entire*, and the surface is found to be covered with fine short hairs, that is, *pubescent*.

Root.—Like the tall buttercup, this plant has a fibrous root.

Classification.—Many plants resemble the asters in having their flowers in heads on a common receptacle, with each head surrounded by an involucre of bracts. With a few exceptions all such plants have been placed in the *Composite Family* or *Compositae*. Besides the numerous species of asters, this family includes the golden-rods, the thistles, the daisies, and many other plants. It comprises quite one-tenth of all the flowering plants known. The arrangement of its flowers in a head is not sufficient, however, to admit a plant to this important family. To find a place there it must have stamens possessing the characteristics of the aster, that is, the anthers united to form a tube about the style (syngenesious), and the filaments separate and attached to the corolla.

CHAPTER VI

POLLINATION AND FERTILIZATION

Before a flower can produce seed its *ovule* must be fertilized. The first step in this process is *pollination*, which is the placing of the pollen on the stigma of the flower. There are two kinds of pollination, *close* or *self-pollination* and *cross-pollination*. In the former, the pollen from the stamens of a flower pollinates the stigma of the same flower. In the latter, the pollen is transferred to the stigma of another flower of the same kind. In nature, cross-pollination is the rule, and by experiment it has been found that seeds of a better quality and in larger quantities are produced by this type of pollination. (See Figure 14.)

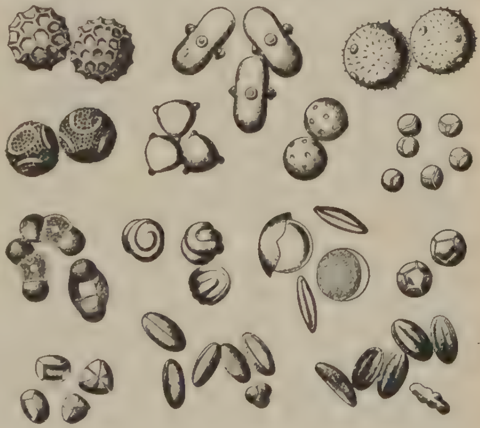


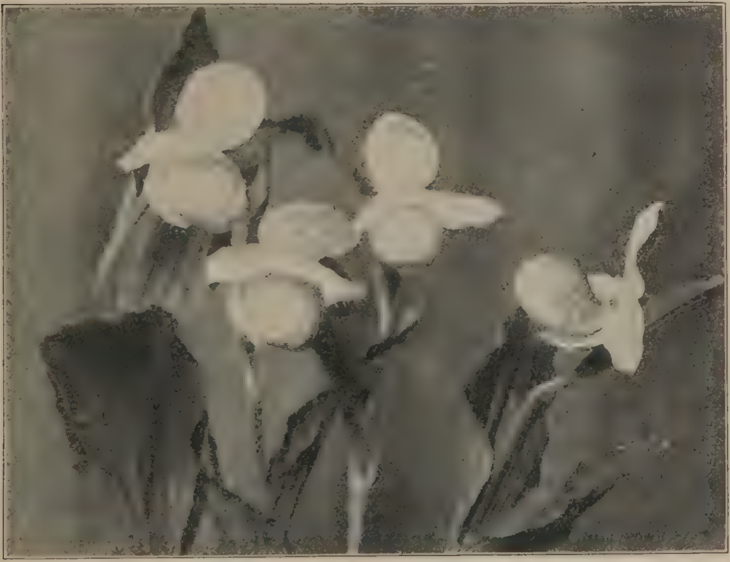
Fig. 14. Pollen grains (very highly magnified). These minute bodies have many different shapes.

Flowers pollinated by insects.—By their bright colours and odours, flowers attract many species of insects. Insects are the most important of the several agents that pollinate flowers, but all insects are not equally valuable as pollen carriers. Beetles and ants, for example, do not assist much in pollination. This is due to several causes. The pollen does not adhere readily to the polished, armour-like coverings of these insects. Moreover, they often make an entrance into the flowers, but fail to follow the path necessary to secure pollination. It is only by chance, therefore, that they are of any value to the plant. Many plants are equipped with ingenious devices which make it difficult for these insects to reach their blossoms. In numerous cases we find defences of much-entangled hairs so arranged on the stems as to make it almost impossible for the insects to crawl up them. If by any chance they do reach the flowers, their entrance into them is often still obstructed by reflexed sepals or a corolla densely covered with hairs.

In general, flying insects play an important part in pollination. Of these, bees are in several ways the best suited for the purpose. Their hairy covering brushes the pollen from one flower and conveys it to the stigma of another flower. As they are strong, they are able to force their way into corollas carefully closed against ants and beetles. Their long, sucking tongues enable them to reach the stores of nectar in flowers with long tubes. This is especially true of the bumble-bee in its relation to red clover, and, as we shall see, makes the relation between insect and plant one of great importance. Owing to the shape of the flower of the red clover, it has to rely almost entirely upon the bumble-bees for pollination and the consequent production of seed. The clover head consists of a number of florets each resembling a miniature sweet pea. At the base of each flower is a long tube containing nectar. So deep is this honey cup that only the long-tongued bumble-bees are able to reach the contents. Consequently, only these insects visit the blossoms and carry the pollen from one to another.

Darwin proved most conclusively that bumble-bees are indispensable to the pollination of red clover. From one hundred heads of this plant from which these bees were not excluded, he obtained 2700 seeds, but, from the same number of heads protected from the visits of these insects, he did not obtain a single seed.

So essential are bumble-bees to the ensuring of a good yield of red-clover seed that attempts, more or less successful, have been made to introduce these bees into districts in which they do not occur. In 1884 two species were imported from England into New Zealand, with the result that the red clover now seeds there plentifully. On their occupation of the Philippines, the Americans found no insects there capable of pollinating the red clover, and in the last few years they have made several



—Courtesy of William Connon, Toronto

Fig. 15. Showy lady's slipper. The very irregular shape of this flower adapts it for cross-pollination.

attempts to introduce bumble-bees. Difficulties have arisen, probably due to climatic conditions, that have interfered with the establishment of the bees in these islands. It is interesting to note that the good-natured, burly bumble-bee is a typical Canadian citizen, being found throughout Canada from the Great Lakes to Hudson Strait.

Another reason why bees are such successful agents of pollen transfer is because they visit many flowers of the same kind in succession, and this practically ensures frequent pollination. Other flying insects, such as butterflies, visit many flowers of different species within a short time, and the pollen carried from a flower of one species is not likely to reach a stigma of the same species.

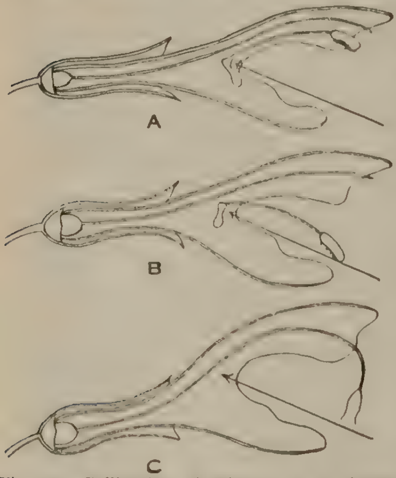


Fig. 16. Pollination of salvia. A, an insect entering the flower in the direction of the arrow, pushes against the lower end of the pivoted stamen. B, The pollen-covered anther of the tilted stamen strikes the insect on the back. C, As this flower is older, the stamens have withered, but the mature stigmas brush off the pollen from the body of the insect, and the pollination of the flower is completed.

Flowers, in their turn, are so constructed as gently to compel their insect guests to make their visits in the way best suited to ensure cross-pollination. (See Figure 15.) In some, a part of the corolla is so placed as to form a convenient landing place for the flying insect. But the perch is always so located that an insect making use of it must enter the flower in such a way as to rub against either the stamens or the stigmas of the flower. In salvia (Fig. 16) and other mints, the stamens are pivoted so that a visiting insect will tip them down and strike the pollen-covered anthers with its back. In an older flower the stigmas are in such a position as to brush the part of the insect's body on which the pollen has been dusted, and the flower is pollinated.

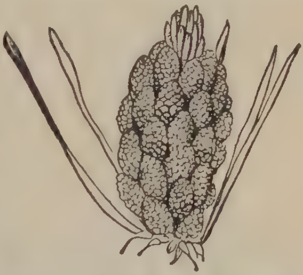


Fig. 17. Stamens of the pine. Would you expect many insects to visit such flowers?

Flowers pollinated by the wind. — The wind is an agent of pollination in importance second only to insects. The grasses, the sedges, and many of our forest trees, such as the oaks, the birches, the pines, and the poplars, are wind-pollinated species. (See Figures 17 and 18.) The flowers of these species have characteristics by which they may be easily recognized. In contrast with the insect-pollinated species, the flowers of the wind-pollinated species are not brightly coloured, and they have neither odour nor nectar. Their pollen is light and dry, while that of flowers pollinated by insects is sticky. As the wind is a wasteful distributor of pollen, a large quantity of it is produced by the wind-pollinated flowers. The pollen of the pines is often seen as a yellow scum floating on the water of our northern lakes. It becomes so plentiful in some districts as to be mistaken for showers of sulphur. In the common ragweed, too, pollen is produced in great quantities, and this pollen is now generally believed to be a cause of hay fever. The corollas of the wind-pollinated

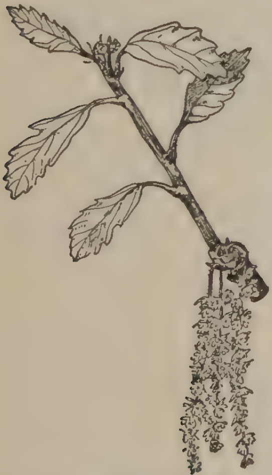
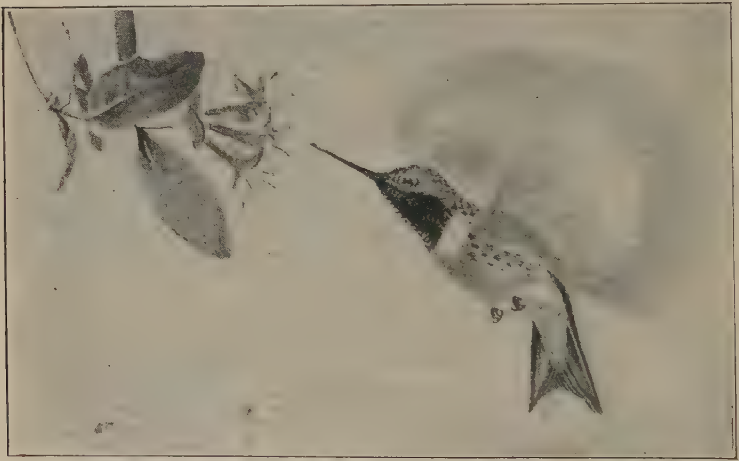


Fig. 18. Flowers of the oak. Is it an advantage to these flowers to be suspended, as they are?

flowers are regular and have not the complicated shapes of those which are insect-pollinated. The flowers of the wind-pollinated species are adapted to catch pollen. Not only are the stigmas feathery, but the flowers are exposed to the wind, either by the elongation of the stems or by the unfolding of the flowers before the leaves.

Other agents of pollination.—Although there is no doubt that snails or slugs do pollinate a few flowers that are close to the ground, they are comparatively unimportant agents of pollination. In Ontario this is true of birds also, since the ruby-throated humming birds (Fig. 19) are the only species that act as pollen carriers. The birds visit our honeysuckles, trumpet creepers, and other flowers with large, tubular corollas, and transfer pollen among them. In parts of South America the many species of humming birds are quite as important in pollination as the insects, and in South Africa they are much more important.



—From "Bird Portraits" by Ernest Seton Thompson, by courtesy of Ginn & Co., Boston

Fig. 19. Why are birds not important agents as pollen carriers?

Water, as an agent of pollination, is interesting rather than important. The flowers of some of our pond weeds never rise above the water, and the stamens liberate their pollen under water. In such species the pollen must float below the surface to the stigmas. The peculiar eel-grass, or tape-grass (*Vallisneria*), opens its pistillate flowers at the water level and liberates its staminate ones below the surface. The staminate flowers rise to the top of the water and, floating against the stigmas of the pistillate flowers, fertilize them. The fertilized flowers are then carried under the water by the coiling and consequent shortening of their stalks.

Prevention of close-pollination and the ensuring of cross-pollination.—In a number of flowers the stamens and the pistil mature at different times and thus prevent close-pollination. When, as in the willows and the poplars, the stamens are on one plant (*staminate*), and the pistils on a different one (*pistillate*), close-pollination is, of course, impossible. If we examine the relative location of the stamens and the pistil in many flowers, it would seem that often a flower's pollen must alight on the stigma of the same flower. It is known that in many cases it does so, but under those conditions fertilization is not so frequent as when the pollen is produced from another flower, because the pollen of a flower usually dries up on its own stigma, and fertilization does not go beyond the initial stage. But some of our plants, such as the partridge berry and the primrose (Fig. 20), have

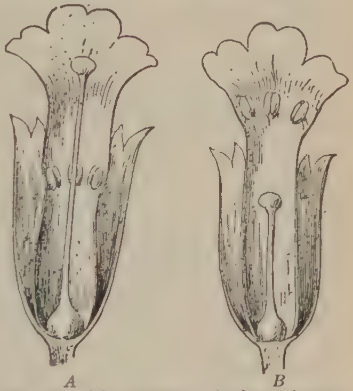


Fig. 20. The flowers of the primrose. A, the long-styled type; B, the short-styled type

both long-styled and short-styled flowers, a device that makes their pollination by insects practically certain. The long-styled flower has its stigma at the top of the corolla tube and its anthers attached half-way up; the short-styled flower is the reverse of this, the anthers are at the top of the tube and the stigma half-way up. This results in an insect being dusted with the pollen from one flower on that part of its body that is rubbed on the stigma of the other type of flower.

Cleistogamous flowers.—Though cross-pollination is the rule among flowers, there are flowers which must be self-pollinated, since they never open. Such flowers are called *cleistogamous* (Greek *kleistos*, closed).

Among our common plants that bear these curious flowers are milkwort (*Polygala*), hog peanut (*Amphicarpa*), and several species of violets, including the common blue species. (See Figure 21.) The cleistogamous flowers on these plants are subterranean, or produced close to the ground, but touch-me-not (*Impatiens*) bears them high up on the plant. These strange flowers are said to produce more seed than the ordinary flowers of these plants.

In the dead nettle (*Lamium*), the cleistogamous flowers appear only in the spring and fall or in cold and rainy weather. It has been suggested that at those times pollen-carrying insects are not plentiful, and many of the open flowers are not pollinated. The lack of seed from them is compensated for by the supply produced from the cleistogamous flowers. The fact that cold weather, lack of sunshine, and poor soil favour, in general, the production of cleistogamous flowers would lead us to suppose that they are emergency devices to meet adverse conditions.

There are certain advantages possessed by these closed flowers, especially when they are subterranean. Being closed, their pollen is protected from rain and from pilfering ants and beetles. Their seeds are hidden from birds, and, when ready to germinate, they are already planted.

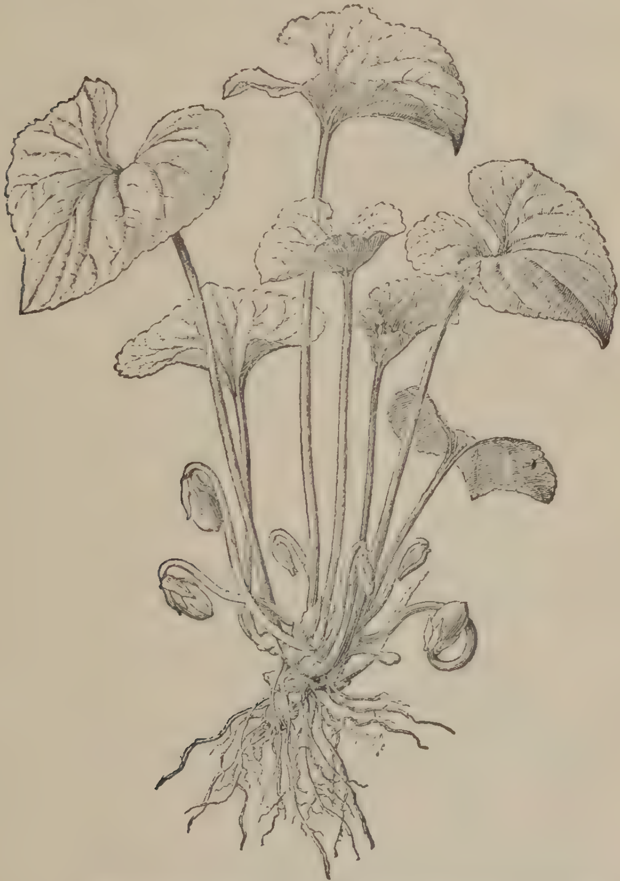


Fig. 21. Cleistogamous flowers. Look for these curious bud-like flowers on our common blue violet.

Fertilization.—This process is a very complicated one, and in an elementary book of this kind must be treated very briefly.

When, by one of the methods already described, a pollen grain reaches the wet, sticky stigma of the pistil, it at once begins a process of growth. The contents of the pollen grain absorb water from the surface of the stigma, swell up, and rupture the outer coat of the pollen grain. The inner coat then grows out into a pollen tube. This tube, into which the living contents of the grain pass, grows down through the tissue of the style out into the cavity in which the ovule or ovules lie, until it reaches the little hole or *micropyle* in the end of the ovule, which it enters. Finally, it arrives at the *embryo sac* in the ovule. Then, by some process not fully understood, the end of the tube opens, and part of its contents passes out and fuses with the *egg cell* in the embryo sac. This is the fertilization of the *egg*.

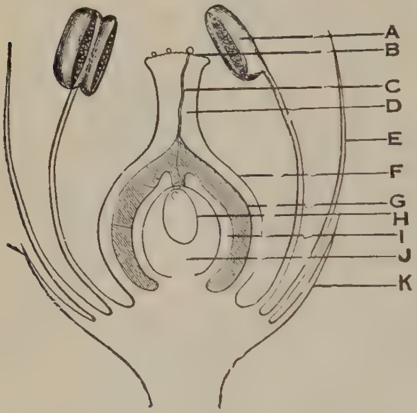


Fig. 22. A section of a flower. A, the anther of the stamen; B, a pollen grain on the stigma; C, the pollen tube; D, the style; E, the corolla; F, the coat of the ovary; G, the interior of the ovary; H, the embryo sac; I, coats of the ovule; J, the interior of the ovule; K, the calyx. The pollen tube enters the ovule through the micropyle.

Following this act, the egg begins to grow, and finally develops into the young plant or embryo that is found in every seed.

PRACTICAL QUESTIONS AND SUGGESTIONS FOR OUTDOOR WORK

1. What insects visit the flowers of the evening primrose or other flowers which open in the evening?

2. Why do these insects visit such flowers?

3. In what way are the visits of these insects an advantage to the plants?

4. What purpose is served by the colour of the flowers?

5. Is it preferable to locate bee-hives near a field of clover or near a field of timothy? Give a reason for your answer.

6. Tie a muslin bag around a small cluster of the blossoms of the apple, the plum, the pear, or the cherry. Do this while the blossoms are in the bud stage. When fruit has begun to form in nearby clusters, examine the covered cluster for fruit formation. Give an explanation of the result observed.

CHAPTER VII

FRUITS

Fruits.—In a popular sense, the term *fruit* is applied only to that part of a plant which contains a seed or seeds and which usually may be eaten raw when ripe. It is not considered applicable to certain other forms. For example, the raspberry, the peach, the plum, and the apple are known as fruits, while the tomato, the cucumber, and the pumpkin are more often termed vegetables. Botanically these are all fruits.

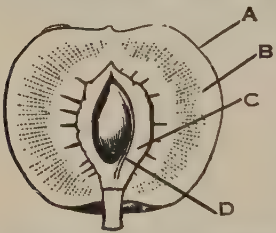


Fig. 23. A drupe or stone fruit, such as a peach. A, the epicarp; B, the mesocarp; C, the endocarp; D, the seed

The term fruit, as used in botany, may be described as a ripened ovary or seed vessel consisting of the ovary wall (*pericarp*) and the seeds. In some cases, however, it is applied to the ripened ovary together with any other structure which may grow to and become a part of it.

The purpose of the fruit is plainly not to supply food for man and animals, although it often does this, but to furnish the seeds with a protective covering while they are maturing. Often, too, it aids in the dispersal of these seeds.

Fruits may be classified as follows:

1. Fleshy fruits, — those having a soft, fleshy texture.

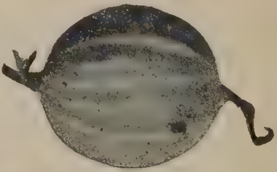


Fig. 24. A botanical berry—a gooseberry

2. Dry fruits,—those having a rather hard and dry covering. Fruits of this class may be sub-divided into—

(1) *Dehiscent*, if the pericarp splits open along definite lines to discharge the seeds.

(2) *Indehiscent*, if the pericarp does not split, but by some means or other is either broken open or worn off.

Fleshy fruits.—1. The *drupe* or *stone* fruit (Fig. 23). If a ripened peach or plum is examined, it is found to consist of four distinct parts: (*a*) the *skin*, which is but the outer layer of the pericarp and often known as the *epicarp*, (*b*) the juicy edible part, known as the *mesocarp*, (*c*) the hard stony covering of the seed or seeds, called the *endocarp*, which is the innermost layer of the pericarp, and (*d*) the seed, or sometimes seeds, found on breaking open the stone.

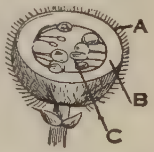


Fig. 25. A section of a berry. A, the epicarp; B, the mesocarp; C, the endocarp containing the seeds

2. The *berry* (Figures 24 and 25). In a popular sense, this term is not used in connection with many fruits known botanically as berries, such as the grape, the tomato, and others mentioned below. When a grape or a tomato is cut in two, no stone is found, but the whole pericarp is somewhat soft and pulpy, with usually many seeds attached in the centre. It is covered on the outside with a skin. Many fruits usually placed in this class show considerable variety of structure, such as the currant, the orange, the lemon, the banana, and the red pepper.

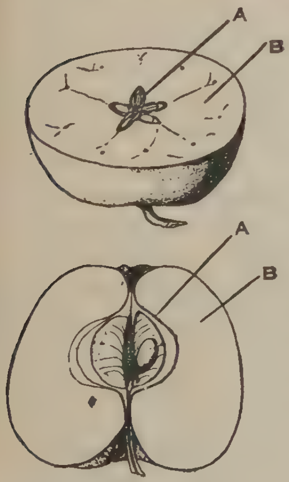


Fig. 26. Sections of a pome. A, the pistil; B, the fleshy receptacle

3. The *gourd* or *pepo*. This fruit, represented by the pumpkin, the squash, etc., has a firm, thick rind, which consists mainly of the enlarged

receptacle grown to and continuous with the walls of the carpels. By some it is defined as a kind of berry with a thick rind.

4. The *pome* (Fig. 26). This fruit, as may be seen from the apple, the pear, or the quince, consists normally of five carpels with tough membranous walls which surround the seeds, and a thickened edible receptacle which is grown to the outside of the carpels. The carpels merely form the core of the fruit.

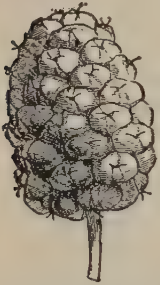


Fig. 27. A multiple fruit of the mulberry. Does one blossom form this fruit?

5. The *multiple* fruit (Fig. 27). This is a fruit with a fleshy axis on which are found the ripened pistils of several flowers. Common examples of this are the mulberry and the pineapple. The pine cone may be included under this type, but it is not fleshy.

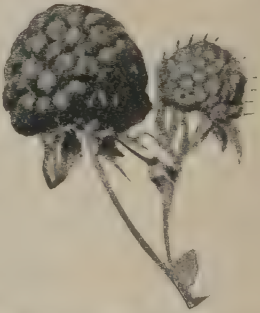


Fig. 28. An aggregate fruit of a raspberry. How many blossoms are there for each fruit?

6. The raspberry and the strawberry are really not berries in the strict sense; the raspberry (Fig. 28) is merely an accumulation of small drupes and is known as an *aggregate* fruit.

7. The strawberry (Fig. 29) is mainly a fleshy juicy receptacle covered with ripened achenes and is called an *accessory* fruit.

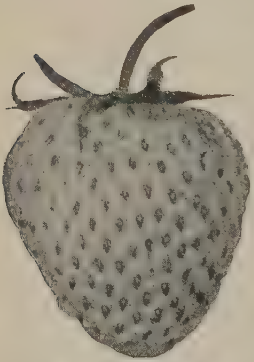


Fig. 29. An accessory fruit of the strawberry. What forms the fleshy part of the fruit?

Dry dehiscent fruits.—1. The *follicle* (Fig. 30). This is a fruit of a one-carpelled pistil which splits on one side only, as in the milkweed and the larkspur.

2. The *legume* (Fig. 31). This is also the fruit of a simple pistil, with two lines of dehiscence on opposite sides of the fruit, such as the fruits of the pea and the bean.

3. The silique (Fig. 32). This is a long fruit, from the sides of which two lids or valves split away, leaving a membranous partition to the edges of which the seeds remain attached. It is a two-carpelled fruit. This is illustrated by the fruit of the wild mustard. When such a fruit is about as short as it is wide, it is known as a silicle. An example of this form is found in shepherd's purse and garden sweet alyssum.

4. The terms *pod* and *capsule* are in common usage applied to any splitting fruit, although capsule is used mainly for a dehiscent fruit of more than one carpel. (See Figures 33 and 34.) The fruit of the iris and the snapdragon are typical capsules; while the fruit of the poppy (Fig. 41) is merely a capsule from a compound pistil which does not split open along regular lines, but opens by numerous pores.

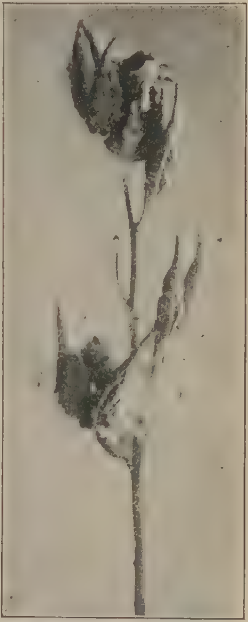


Fig. 30. A follicle of a milkweed. What agent distributes the seeds of this plant?

In all dehiscent fruits the seeds are attached, at first, to definite points or ridges inside the ovary. This place of attachment is called the *placenta.*

Dry indehiscent fruits.—1. The achene, such as the so-called seeds of plants like the thistle, the aster, and the buttercup (Fig. 35), consists of a small, one-seeded fruit.

2. The *grain* is a fruit in which the one seed completely fills the pericarp, the seed coats and the pericarp being fused

into one covering. This fusion does not take place in the case of the achene. Our common grains and cereals, such as wheat and barley, are the best illustrations of this type.

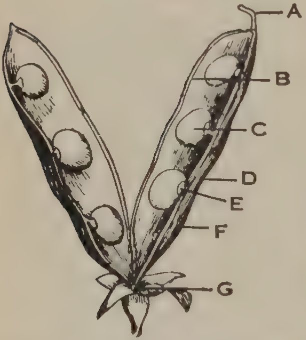


Fig. 31. A legume. A, the stigma; B, the line of dehiscence; C, the seed; D, the line of dehiscence; E, the stalk of the seed; F, the coat of the fruit; G, the calyx

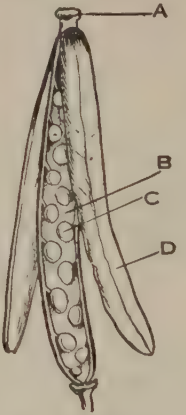


Fig. 32. A silique. A, the beak; B, the partition; C, the seed; D, the valve

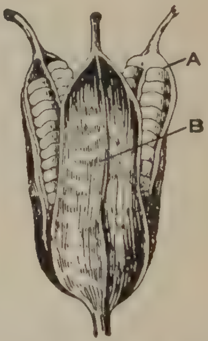


Fig. 33. A capsule of an iris. A, the seed; B, the valve

3. The *nut* is much like the achene, but is usually larger, with a hard shell, and is, in most cases, inclosed in an involucre. Typical nuts are the acorn, the chestnut, and the beech nut. Some fruits which are called nuts are, however, either somewhat different from this or are not true

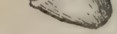


Fig. 34. A pyxis—a special capsule of the purslane

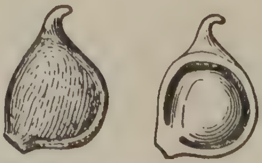


Fig. 35. An achene of a buttercup. In the figure on the right the achene is cut open to show the seed.

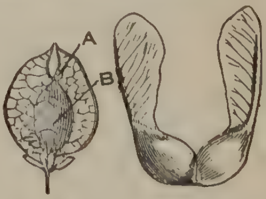


Fig. 36. A samara. A, the wing; B, the seed. On the right is shown the double samara of a maple; on the left, the samara of an elm.

nuts at all. The hickory nut is a nut with a husk which is derived from the involucre, and which splits off in four sections when mature and dry. The cocoa-nut is a kind of drupe, the hard shell of which is the endocarp, the fibrous mesocarp and the epicarp having been removed before shipping. The walnut is a dry drupe having a rough jagged endocarp, and the Brazil nut is but a seed with a hard outer covering.

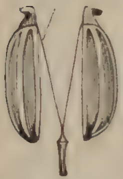


Fig. 37. A schizocarp of such a plant as the carrot

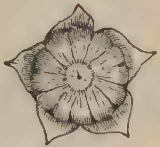


Fig. 38. A schizocarp. Of what plant is this the fruit?

4. The *samara* or *key* (Fig. 36) is an achene supplied with a thin wing attached at one end or completely encircling it. We see familiar examples of this in the ash and the elm. When two winged fruits are attached together, as in the maple, the term *double samara* is used.

5. The term *schizocarp* (Figures 37 and 38) or splitting fruit is applied to fruits which split up into one-seeded pieces that do not dehisce. The fruit of the maple is also an example of a schizocarp, as the two keys finally break or split apart.

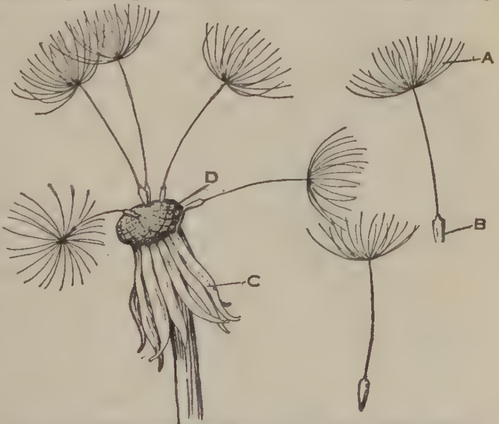


Fig. 39. A fruiting dandelion head. A, the plume; B, the achene; C, the bracts; D, the receptacle. Name other plants with plumed fruits.

The dispersal of seeds and fruits. — It is of the greatest importance to each plant species that its seeds should travel some distance from the parent plant. The very existence of the plant depends on this. Otherwise, overcrowding would prevent the seedlings from securing the proper amount of food and light. As plants cannot themselves move about as animals do, they must have the assistance of various agents and devices to procure their food and protection. This they do through their seeds and fruits, or often by other parts such as stems and roots. These parts of the plants sometimes travel even much greater distances than animals. It is well known that some seeds and fruits are carried thousands of miles across continents and oceans before they have a chance to germinate. We have many instances of this distribution of species over wide areas and from one country to another. For example, such troublesome weeds as the wild mustard, the shepherd's purse, the blue-weed, the purple cockle, and many others have come to Canada from Europe. The

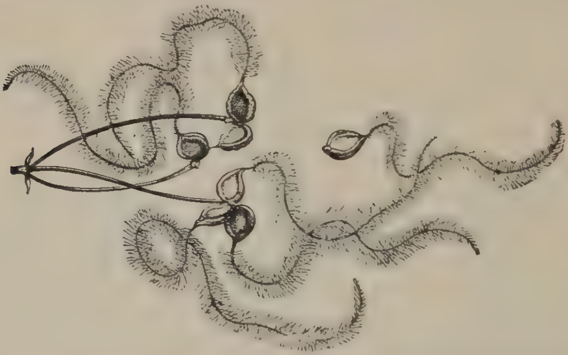


Fig. 40. The wild clematis. This plant has an efficient aeroplane service for its fruits.

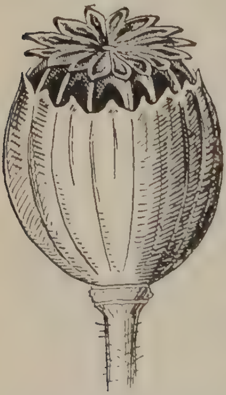


Fig. 41. The fruit of the poppy. How are the seeds thrown out of this capsule?

Russian thistle has spread from Asia, and the redroot pigweed from tropical America. The tumbling mustard, introduced in 1887 into the Prairie Provinces, has since travelled eastward into other parts of Canada, and is now common in some of our large cities, although it has not yet become a pernicious farm weed. Many other similar cases of weeds spreading might be added to the above list.

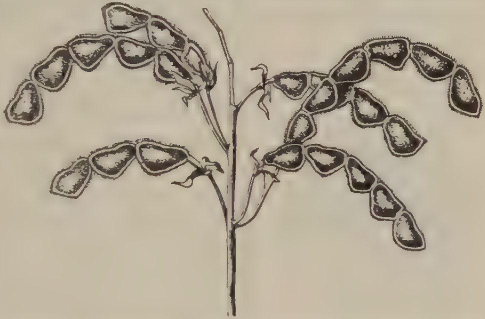


Fig. 42. Tick-trefoil. This fruit breaks off in sections that form burs.

For such a scattering and distribution of plants by means of seed and fruit dispersal, one or other of the following agents is in most cases responsible:

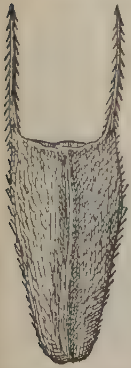


Fig. 43. The bootjack bur. Of what plant is this the fruit? Can you name other plants, the fruits of which are burs?

1. *Wind.*—Many examples of this method occur in the case of the winged fruits of the maple, the elm, the ash, the basswood, and others, in the seeds of the milkweed, and in the fruits of the dandelion (Fig. 39) and the thistle, with their tufts of light hairs; in the fruits of the clematis (Fig. 40) with its long hairy styles; and in so-called tumbling plants such as the Russian thistle, the pigweed, and in the tumbling mustard. A plant of this last species has been found to produce as many as 1,500,000 seeds. By the time that the seeds of such a plant ripen, the top of the plant dries up, breaks off near the ground, and is blown about over fields and prairies for a whole winter, scattering its seeds at intervals over large areas.

2. *Water.*—This is a very common agent, particularly amongst plants growing near streams, ponds, and marshes. An examination of the seeds and fruit of such plants shows that many of them are constructed to float on water. They are either boat-shaped or filled with air-tight compartments. The marsh marigold and many sedges have such fruits. Other plants have seeds or fruits supplied with corky margins. Examples of this type are found in the fruits of the water dock and the arrow-head and in the seeds of the milkweed. Winged and hairy fruits and seeds will float for some time if they happen to drop on water.

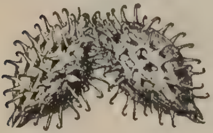


Fig. 44. The common cocklebur

3. *Animals.*—Many plants make use of animals of various species to accomplish what they themselves are unable to do. We see that cattle, sheep, squirrels, birds, and even insects are unwittingly made the agents of transportation. Cattle and sheep in the pasture or woodland gather burs of the hound's tongue, the stickseed, and the burdock (Fig. 45) on their bodies, and carry them about, finally rubbing them off, or dropping them perhaps some distance away. Attracted by brilliant colours or possibly by suggestive odours, squirrels, chipmunks, and birds seek and devour nuts, seeds, and berries of various kinds, or collect them to store up for their winter's food. Often they drop these along the way or forget the hiding-place. Squirrels actually gather and plant acorns or other nuts by digging them into the ground, and there is little doubt that many oaks have started in this way.

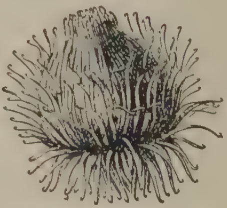


Fig. 45. The fruit of the burdock

4. *Man.*—As an agent of seed, fruit, and plant dispersal,

man probably exceeds in importance any other. He is the direct means of transporting grains, and with them weed seeds, from one country to another. He introduces into his own country many new varieties of trees and plants, and he assists nature in increasing the productiveness of many plants.

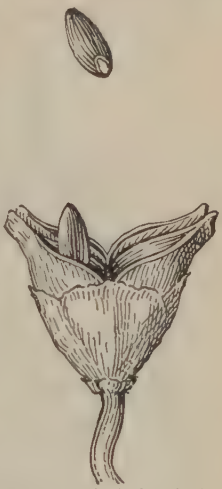


Fig. 46. A fruit of the witch-hazel

5. *Special plant mechanisms.*—Many plants have special and peculiar adaptations for seed dispersal. Some have natural devices for shooting or expelling their seeds from the capsule, just as an apple seed may be shot from the fingers. One very striking case of this is found in the witch-hazel (Fig. 46), a common shrub. Its hard, nut-like fruit when mature splits open on the end, and, by pressure on its hard, smooth seeds as it opens, it shoots these to a distance sometimes of twenty-five feet or more. The touch-me-not or balsam (Fig. 47) has an elastic pericarp which when mature suddenly explodes if touched, and forcibly ejects its seeds. The pea, the bean, the lupine (Fig. 48), and the hog peanut have legumes which split open in such a way that each half suddenly twists, flinging its seeds in two directions. The fruits of the hog peanut when dropped on a table were, in one instance, observed to throw seeds a distance of twenty feet across a room.

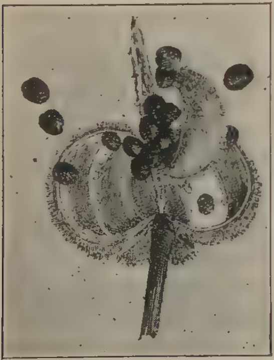


Fig. 47. A fruit of the balsam

There are many other ways by which plants prevent crowding. One actual example will serve to illustrate. A plant of twining Canadian moonseed had been transplanted from a field to the garden. For a few years it flourished, but later it became too aggressive, and, for the benefit of surrounding plants, it was removed. The following year, new stems from shoots that had not been disturbed shot up in a different spot. These also were uprooted, but again new shoots started up just a little beyond, and finally the plant was allowed to grow undisturbed. It now forms, with its thick, dark green, glossy leaves, an attractive screen.

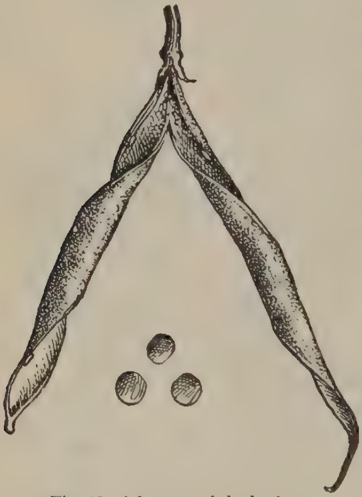


Fig. 48. A legume of the lupine

Practical Questions and Suggestions for Outdoor Work

1. Name three plants, the seeds of which are adapted for dispersal by the wind.

2. Name three other plants, the seeds of which are transported by animals.

3. How are the fruits of the following plants dispersed: Elm, ash, buttercup, sow thistle, clematis?

4. Classify the fruits of the following plants: Morning glory, horse-chestnut, thistle, orange tree, hawthorn, currant, plum.

5. Name four trees or shrubs that produce edible nuts.

6. Name six trees or shrubs that bear fleshy edible fruits.

7. What difference is there in the height of the flower stem of a dandelion in flower and in fruit? Of what advantage is this to the plant?

CHAPTER VIII

FUNGI

The group of plants known as fungi includes many species very unlike one another, but all alike in possessing no *chlorophyll* or leaf-green. The lack of this substance distinguishes them from the green plants which we have discussed. The fungi are not able to manufacture sugar or starch from carbon dioxide and water, as can the chlorophyll-bearing plants. Therefore it is necessary for them to obtain their food in a prepared form, and to do this they must follow either a *saprophytic* or a *parasitic* mode of life. If the former, they absorb nourishment from decaying organic matter, if the latter, from living plants and animals.

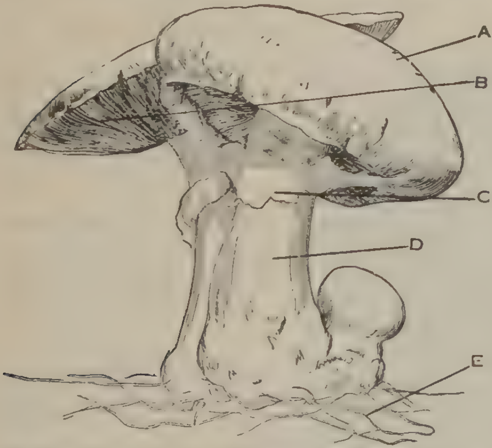
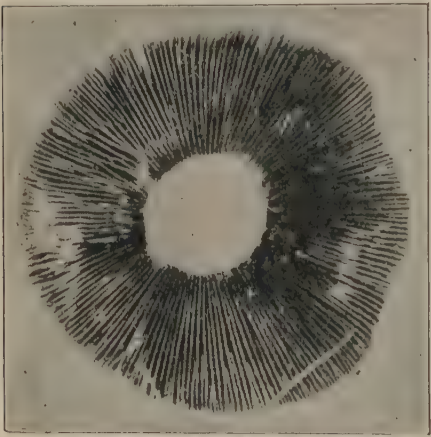


Fig. 49. The common mushroom. A, the pileus; B, the gills; C, the ring; D, the stipe; E, the mycelium

Gill fungi.—The common mushroom (Fig. 49) will serve as a type of a saprophytic gill fungus. The part of the plant above the soil consists of an umbrella-shaped *cap* (*pileus*), borne on a *stalk* (*stipe*). Around the upper part of this stalk is a membrane-like *ring,* and on the under surface of the cap are to be seen the thin plates, known as *gills.* These are close together and extend out from the stalk in radial directions. A compound microscope is necessary to reveal the detailed structure of the gills. A prepared section of them will show that the surface of each is the spore-producing layer. This production of *spores* is the function of the aerial part of the mushroom.

The relation of the spores to the gills can be shown by making what is known as a spore-print (Fig. 50). To do this, cut off the stalks of a mushroom at about half-an-inch from the gills. Stand the mushroom on a sheet of paper or plate of glass, and exclude all air currents with a bell jar or by other means. Examine after several hours.



—Courtesy of World Book Co., Yonkers, N.Y.

Fig. 50. The spore-print of a mushroom

Under the ground, at the base of the stalk and attached to it, is a mass of fibres (*mycelium*). This part of the plant absorbs food from the decaying matter upon which it is growing. The above-ground part of the mushroom arises as so-called "buttons" on the mycelium. Each button develops a stalk and cap with its gills. The gills are covered by a membrane, the *veil,* which extends from the edge of the cap to the stalk. The mature mushroom still has the remains of this veil as the ring surrounding its stalk. The "spawn" sold to start mushroom beds is a mass of earth and vegetable material in which the mushroom mycelium has been growing. Placed under proper conditions of warmth and moisture the fibres in the spawn will recommence development and will soon produce a crop of mushrooms.

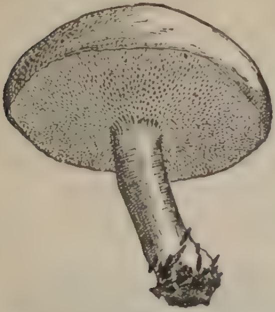
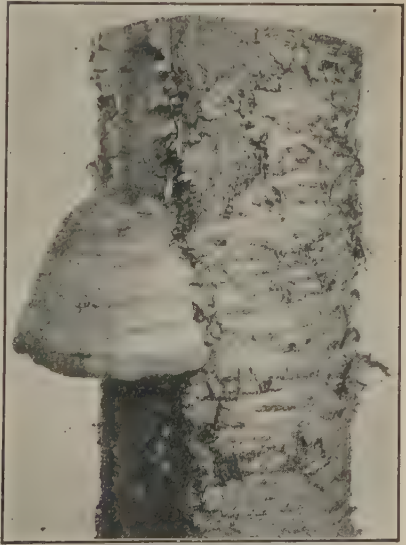


Fig. 51. The umbrella-shaped boletus

Pore fungi.—These fungi resemble the mushrooms in their method of reproduction. The spore-producing part in this group, however, does not cover radiating gills, but lines certain tubes that open directly to the outside. Hence these forms are known as *pore* fungi. Some species, such as those of the genus boletus (Fig. 51), have the umbrella shape of the mushroom, but the more commonly occurring forms are the well-known bracket or shelf fungi found on trees, logs, and stumps. (See Figure 52.)

In one species of the bracket fungi the pore surface is pure white, although it is soiled very easily by contact with other objects. Sometimes these white surfaces are used as drawing tablets, since sketches made on them with a sharp point remain permanently when the fungus dries. The pores of the bracket fungi are always on the under side of the

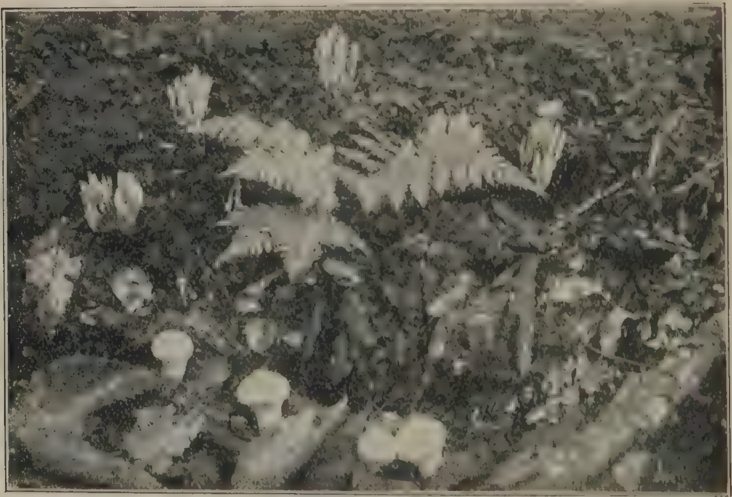


—*Courtesy of J. H. Faull, Toronto*

Fig. 52. Bracket fungus on a birch tree

outgrowth. If the tree on which it is growing happens to fall, the direction of growth of the fungus is changed so as still to keep the spore-producing layer on the under side of the bracket. This is true only if the brackets are perennial.

The mycelium of most of the bracket fungi grows on the inside of the tree or stump, only the spore-producing part appearing on the outside. If the tree attacked by the fungus is living, the fibres of the mycelium penetrate chiefly the dead tissues of the heart wood. The spores of these fungi are produced so abundantly that a fungous disease once introduced soon spreads and becomes serious. It has been estimated that a single pore of a bracket fungus on an elm produced 1,700,000 spores in three days, and at that rate the whole spore-producing part liberated four billion spores.

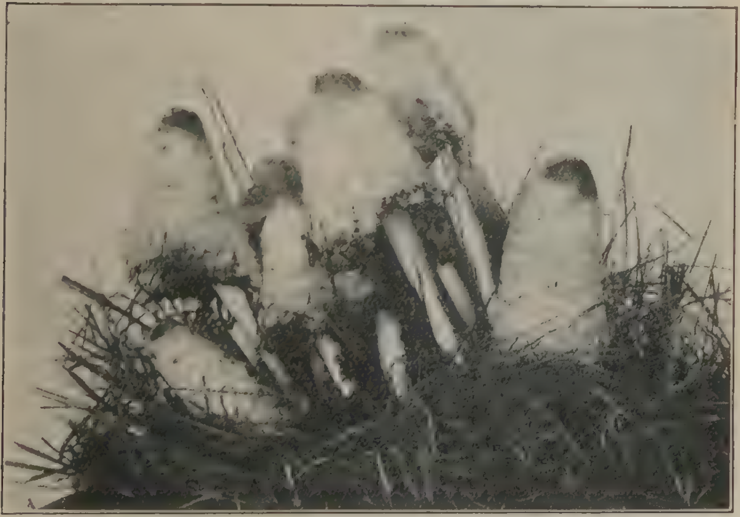


—*Courtesy of the World Book Co., Yonkers, N.Y.*

Fig. 53. Puffballs in the foreground, and coral fungi in the background

Puffballs.—These fungi differ from both the gill fungi and the pore fungi in having the spore-producing layer completely inclosed until the spores are mature. The puffballs are saprophytic, and the mycelium is subterranean. They vary in size from a diameter of less than half-an-inch to eighteen inches. (See Figure 53.)

As in the other fungi, the spore-producing part is aerial. It is usually somewhat globular in shape and has a distinct skin on the outside. When the puffball is mature, the inclosing wall is ruptured, allowing the dark-coloured spores to escape. The puffballs are so well known that everyone must have seen the "smoke" (spores) puff out from them when they were submitted to sudden pressure. The large, whitish puffballs often seen in old meadows and stump fields, as well as other species, are edible. (See Figures 54 and 55.)

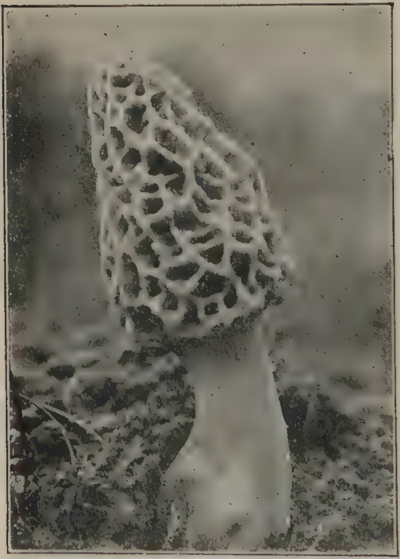


—*Courtesy of J. H. Faull, Toronto*

Fig. 54. Shaggy-mane fungus, an edible gill fungus

Poisonous fungi.—In spite of the comparative rarity of the deadly species, too much care cannot be exercised in the selection of mushrooms for the table. There are several species of gill fungi in Ontario that have often produced fatal results, even when eaten in small amounts. Two of these—the deadly amanita and the destroying angel (Fig. 56)—closely resemble each other.

The latter is all pure white, while the upper surface of the cap of the former is pure white or varies from white to amber through shades of yellow and green. Both species have the characteristic of springing from a bulbous base inserted in a cup-like receptacle (*volva*). In order that this very important feature may be observed, the plants must be dug carefully, as the stalks break easily. A ring or collar is commonly present a short distance below the gills. The caps of these forms are smooth and never scaly.



—*Courtesy of J. H. Faull, Toronto*

Fig. 55. The common morel. This fungus is not only edible but also very delicious.

The deadly amanita and the destroying angel contain an extremely poisonous substance. So active is it that even handling specimens of the fungi will in some instances produce unpleasant symptoms. It is difficult to recognize this poison, as it does not give the mushrooms a disagreeable taste. There is no evidence of poisoning for at least twelve hours after eating these species, and, since no antidote has been discovered, death usually results a few hours later.

A near relative of the two preceding is the poisonous fly agaric, so called because infusions of it have been used as a fly poison for hundreds of years in Europe. Its stalk also is expanded at the base into a bulb, which is often surrounded with scaly rings. The cap is yellow to orange or red in colour and, at least in young plants, covered with scales that are usually white. These warning colours lessen greatly the possibility of this being mistaken for an edible species.

The violent poison contained in the fly agaric has a sufficiently displeasing taste to lead to the identification of this fungus before much of it has been eaten. Atropin is the antidote administered in suspected cases of poisoning by this species. The preliminary symptoms of the action of the poison appear usually within a few minutes after it has been eaten, but cases which do not respond to the antidote do not as a rule terminate fatally until after two or three days have elapsed.

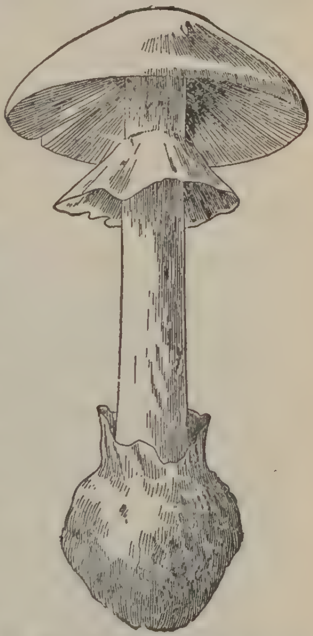


Fig. 56. The destroying angel. The cup-like bulb at the base of the stalk marks out this deadly poisonous species.

There are many so-called tests for distinguishing edible from poisonous fungi, but general rules, such as the mushroom turning a silver spoon black or not peeling readily, are entirely untrustworthy for determining the deadly forms. Each species must be identified from its own individual characteristics.

In collecting fungi for food it is important to remember that decomposed plants or any species burrowed by insect larvae should not be gathered; unless the fungus is well known, immature forms, "buttons," are unsafe, since they are not yet sufficiently developed to admit easily of positive identification; and fungi with swollen bases arising from cups or bearing scaly rings should also be avoided.

FUNGI PARASITIC ON PLANTS

Apple scab.—The most serious disease of apples in Ontario is the apple scab, which is produced by a parasitic fungus. Evidences of the disease may be found on the fruit, the leaves, and the blossoms, and more rarely on the twigs. The fruit and the leaves are the parts most seriously affected, and to them the greatest damage is done. The disease is easily recognized from the black or brownish, often grayish-bordered, spots on the fruit. Examples of the scab spots may be found in almost any basket of apples, but some varieties are more susceptible to the disease than others. The snow apple and the St. Lawrence are very often infected with scab, while the golden russet and the Tolman sweet are unsusceptible.

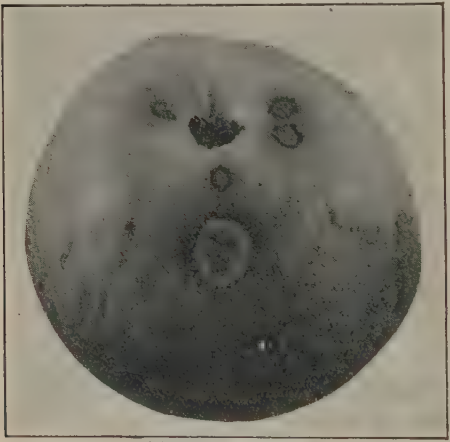


Fig. 57. Apple scab

With the aid of a microscope, the scab spots can be seen to be made up of threads of the fungus (*hyphae*) and minute spores. The hyphae have been produced under the epidermis of the apple, but have ruptured it by their growth. Thus the spores are on the outside, where they are easily washed off by the rain or carried away by the wind and insects. Those that come to rest on the fruit or the leaves of an apple tree are likely to germinate if supplied with sufficient moisture. In germination the spore penetrates the epidermis of the host with a minute thread, known as a *germ tube*. In about two weeks from the time that this occurs, the scab spot appears. By the distribution and germination of the spores it is possible for the disease to be passed from one tree to another throughout the whole orchard.

The scab fungus is carried over the winter on the fallen leaves of the host. On these, in the spring, are found small black dots, which are spore-producing or fruiting bodies. Inside of them are tiny sacs, each of which contains eight spores. When mature the fruiting body opens by a minute pore, and through it the spores are shot out. The spores are not only distributed by the force with which they are discharged, but they are also scattered by the wind. Some of them are certain to reach an opening leaf or flower bud and germinate there, as did the other kind of spores. As a result of this, the first crop of scab spots is produced on the flowers and the leaves.

The apple-scab disease is injurious in several ways. Scabby fruit not only does not look as well as clean fruit, but is more subject to rot. Sometimes, also, the infected apples are stunted and deformed. Moreover, the vitality of a plant is lessened by any injury to its leaves, since their ability to manufacture food is impaired.

Control measures.—To prevent the apple-scab disease, it is necessary to spray thoroughly with either lime-sulphur or Bordeaux mixture from three to six times in the season. The number varies, as spraying must be done more frequently if the season is wet.

Black knot.—A well-known parasitic fungus is the one that causes the black, rounded, often spindle-shaped swellings on the limbs of cherry and plum trees. As a rule these deformities do not completely encircle the stem. Because of these swollen masses, the disease is known by the common name of black knot. The disease produced is very destructive, and many of the trees in the older orchards of Ontario have been badly damaged or killed by its ravages. The fungus not only infects cultivated cherries and plums but also attacks the wild species of these trees.

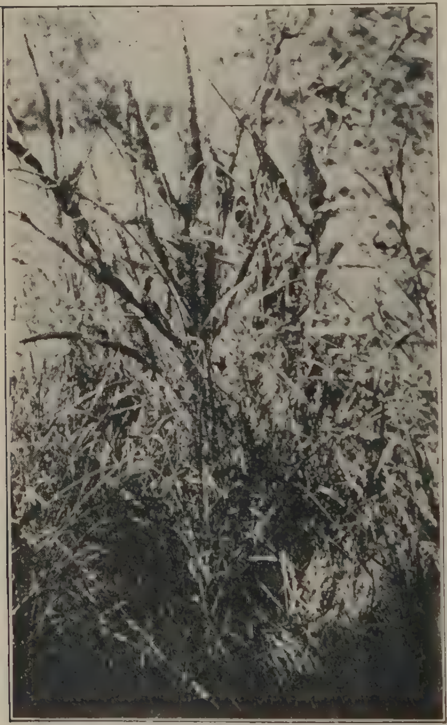
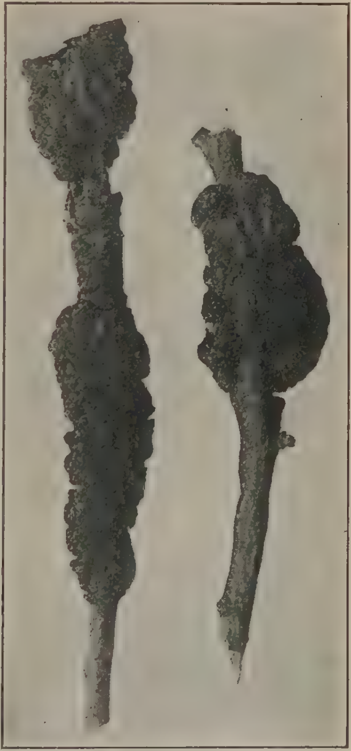


Fig. 58. Black knot. In this instance the disease has attacked a wild plum.

At first, the mycelium is in the bark or under it. Later, it breaks through to the outside, and, with the swollen bark, forms the black masses or knots on the branches of the tree host. During the late spring and summer, short stalks arise from the surface of the fungus, and from these are produced spores which are a source of infection to other trees. This spore-producing stage is easily recognizable from the velvety appearance of the surfaces of the knots. In the autumn, small flask-shaped bodies appear on the surface of the knot. These are lined with minute sacs, each of which contains eight spores. The spores are not liberated until spring, at which time they escape from the sacs and are distributed by the wind. The trees are then just opening their buds, and many are likely to be infected by the spores. It is these spores that form the mycelia referred to on page 54.

Control measures.—Cut out and burn the swollen masses. In cutting, remove enough of the branch below each knot to include all the diseased part. According to a clause of the *Fruit Pests Act*, black knot must not be allowed to remain in orchards.

Remove all the wild plums and cherries that show signs of the disease and are close enough to the orchard to be a source of infection.



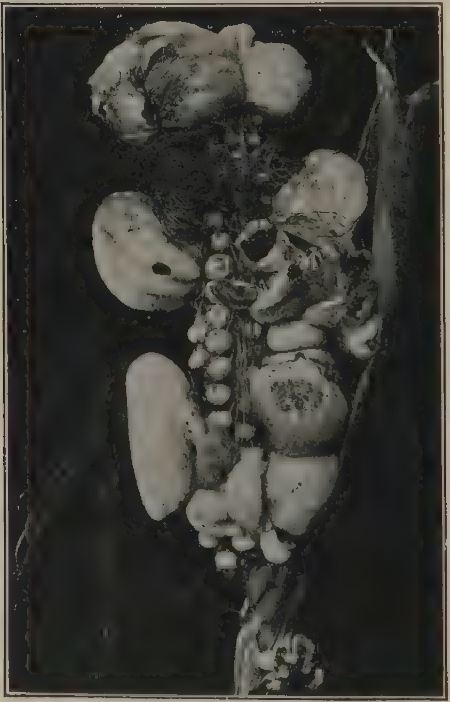
—Courtesy of Ontario Department of Agriculture

Fig. 59. Plum twigs, showing the more detailed structure of black knot

Spray with lime-sulphur so thoroughly that the trunks and the limbs of the trees are covered with the liquid.

Smuts.—These parasitic fungi affect especially corn and other cereals, such as wheat, oats, and barley. When such cereal crops are badly infected, serious losses result. It has been estimated that the corn crop of Ontario is damaged to the extent of $140,000 each year.

Corn smut.—This fungus does not usually betray its presence until the ears and "tassels" form on the affected plants. Then white, lustrous blisters appear. These soon change to large swellings, which deform the kernels of the cobs and the stamens of the tassels. Also, parts of the stem, the leaves, and even exposed roots are affected. On the outside of each deformity is a membrane-like covering, and beneath that a mass of fungus threads. The latter cannot be seen without the aid of a compound microscope. The threads will be recognized as a part of the mycelium of the fungus that has appeared on the outside for spore production.



—Courtesy of Ontario Department of Agriculture

Fig 60. Corn smut at a fairly early stage. The black spores will be discharged later.

Later, the swellings become larger and sooty black in colour. An examination at this stage will show the covering ruptured and a black mass protruding. A little of this examined under the microscope reveals the fungus threads changed to black, thick-walled spores. These are carried about by the wind, and remain unchanged in the ground over winter. In the spring they germinate and give rise to spores. These spores remain in the soil for some time and affect the plant when it is a foot or more in height.

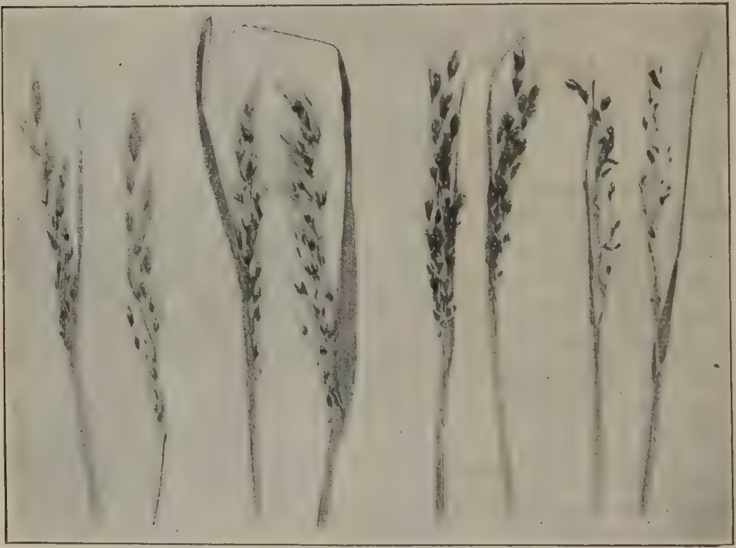
Control measures.—Remove and burn all smut swellings as they appear. If this is not done, spores carried from them will infect other plants.

Leave as little manure as possible in the soil, as it furnishes nourishment, in the spring, for the germinated spores.

Rotate the crops, so that corn will not be grown oftener than every third or fourth year on the same field.

Loose smut of oats.—Like the corn smut, this fungus produces its spores in the flower clusters. In these the kernels are changed to dark brown, sooty masses. The millions of spores that result from them are distributed in all directions by the wind, and some are certain to reach healthy heads. If they get inside the hulls of these and lodge on the kernels, they remain there dormant until spring. They then germinate, and at the same time the sown oats which carry them commence to sprout. The tiny fungus threads produced by the spores penetrate the young seedlings and follow up the stems as they elongate. The fungi are not noticeable in the infected plants until their time of heading out. When that occurs, the spore masses are again formed, and the spores are blown about, many of them to secure lodgment on plants still free from the fungus.

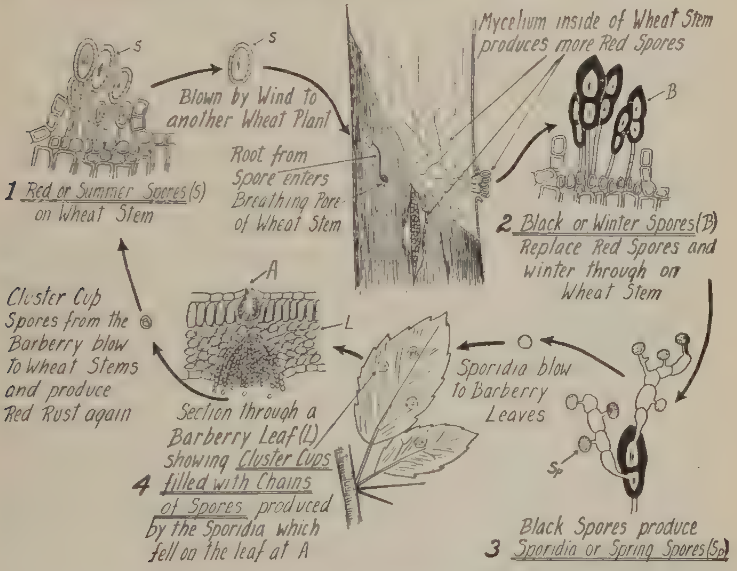
Control measures.—As we have seen, the grains of the oats carry the smut spores over winter, so care must be taken to kill them on all oats that are to be used as seed. This is done by treating the seed grain with formalin. The following is a common method of doing this: Prepare a solution by mixing one pint of formalin (forty per cent formaldehyde) with forty gallons of water. This should be sufficient for the treatment of between fifty and sixty bushels of oats. Sprinkle the pile of seed grain with the solution. Shovel the heap of grain into another pile, mixing as thoroughly as possible. Sprinkle as before and again shovel. Repeat these operations until every grain is wet with the solution. Then cover the pile of grain with bags or sacking soaked in the solution, and leave for three or four hours. At the end of this time, spread the grain out to dry, hastening this process by shovelling it over several times.



—Courtesy of Ontario Department of Agriculture

Fig. 61. Loose smut of oats

Rusts.—Plants that are serving as hosts for the rust fungi are easily recognized by the reddish-brown, elongated spots that occur on their leaves and stems. The spots are due to the fungi producing at certain stages rust-coloured spores. Rusts are found on many varieties of plants, over 2000 species being known. They are especially destructive to such cultivated grains as wheat, oats, barley, and rye.


Mycelium inside of Wheat Stem produces more Red Spores
S
S
Blown by Wind to another Wheat Plant
B
Root from Spore enters Breathing Pore of Wheat Stem
1 Red or Summer Spores (S) on Wheat Stem
2 Black or Winter Spores (B) Replace Red Spores and winter through on Wheat Stem
A
L
Cluster Cup Spores from the Barberry blow to Wheat Stems and produce Red Rust again
Sporidia blow to Barberry Leaves
Section through a Barberry Leaf (L) showing Cluster Cups
4 filled with Chains of Spores produced by the Sporidia which fell on the leaf at A
Sp
Black Spores produce
3 Sporidia or Spring Spores (Sp)

—*Courtesy of H. C. Andrews, Regina*

Fig. 62. A diagram illustrating the four stages in the life history of the black or stem rust of wheat, as seen through a microscope. Follow the arrows.

Wheat rust.—Wheat-growers suffer heavy losses from this fungus every year, but particularly in wet seasons. The parasite not only robs the wheat of a considerable part of the starch manufactured by the leaves, but the rust spots on the leaves make them less efficient in the work of photosynthesis. The result is that the heads of wheat in a badly-rusted crop are not well filled, and the kernels are small and light.

The best time to commence the study of the rust is when the rusty-brown streaks first appear on the leaves and stems of the wheat plants. A little material from one of these spots is shown by the microscope to consist of a mass of spores. These are known as *summer* spores. Toward the end of the season black streaks are to be found on the host plants. Again the microscope will reveal these to be masses of spores. As these carry the fungus over the winter, they are called *winter* spores. The spores in this instance, besides being dark-coloured, also differ from the summer spores in having thicker walls inclosing two cells.

The winter spore remains on the ground on stubble or straw until spring, and then germinates, forming a four-celled mycelium. Each cell of this produces a spore known as a *spring* spore. At this stage the strangest part of the life history of the rust occurs. The spring spore does not infect wheat plants, but usually attacks an entirely different plant, the barberry. On the epidermis of this plant the spore germinates and forms a mycelium in the leaves. Later, this mycelium produces, on the lower surface of the leaves, many minute cup-like structures known as *cluster cups*. In each of these cups are columns of yellow-coloured spores. These spores are distributed by the wind, and, if they alight on a wheat plant, they germinate. As a result of germination, the spores send out tubes, which gain access to the interior of the leaves of the wheat plants. The mycelium, which is soon formed, breaks through the epidermis, producing the summer spores, and the life history of the wheat rust is complete.

Control measures.—Wheat fields should be well drained, as rust is apt to be more destructive on poorly drained than on well drained soil. Much work has been done in attempts to develop varieties of wheat not affected by rust, but, up to the present, these efforts have not met with uniform success. There are, however, some varieties of wheat that are not so subject to rust as others.

It is now contrary to law to plant the common barberry (*Berberis vulgaris L.*), as it has been proved that the presence of this plant increases the severity of a rust outbreak.

FUNGI PARASITIC ON ANIMALS

Animals, as well as plants, furnish hosts for parasitic fungi. One of the deadliest enemies of the house-fly is a plant known as the fly fungus. Flies that have been worsted in their struggle with this foe are often seen adhering to window-panes. Around each victim is a smoky halo composed of the spore cases and threads produced from the fungus by which the fly has been attacked. The body of each fly killed by this plant is, in consequence, a source of infection for other flies, since, from the threads composing the halo spores are continually floating off into the atmosphere, where they come in contact with healthy flies. On account of the sticky coat on the outside of each spore, it readily adheres to the body of any fly which it happens to touch. From the spore a tube is sent out that penetrates the skin and spreads throughout the body of the insect, absorbing the fatty substance in its course. This continues until the doomed victim is so exhausted that it cannot continue longer on the wing and settles down to rest. The very fine, spore-producing threads, which are pushed out by the fungus, fasten the fly to the object on which it has alighted, and with the spore cases produce the halo-like appearance around it.

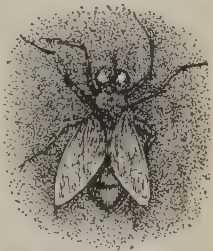


Fig. 63. A fly that has been killed by a fungus

Insects other than flies have plant enemies. In the years when grasshoppers are particularly numerous, many of them are killed by fungus attacks. In such seasons the stalks of timothy and other grasses frequently bear the dried bodies of the grasshoppers that have clung to them and died there.

Several insects are known to be attacked by fungi when in the larval stage. The white grubs, larvae of the May beetles or June bugs so destructive in different parts of Ontario, are checked materially by the attacks of fungi. The infected specimens may be recognized by the long, fleshy stalk of the fungus that projects from the under side of the body just back of the head. (See Figure 64.) Wireworms, the larvae of the click beetles, are also attacked by a similar fungus. There seems to be no doubt that, in each of the examples noted, the fungus is of considerable economic importance in preventing the too rapid increase of an injurious insect.

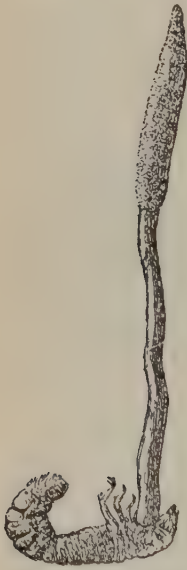


Fig. 64. A May beetle larva attacked by a fungus

A remarkable example of an insect attacked by a plant is furnished by the larva of a New Zealand moth (Fig. 65). The relation between this insect and the plant is almost identical with that of the white grubs and the wireworms. The threads of the fungus penetrate in all directions throughout the body of the caterpillar, which, in spite of this, attains to almost its full size and enters the ground to pupate. Its failing strength prevents this change from taking place, and it dies. The fungus continues to grow until it reaches maturity, when from the body of the caterpillar it sends up above the ground a stalk, on the end of which spores are produced. The dissemination of these spores by the wind leads to the infection of other caterpillars. In the meantime, the body of the larva has disappeared, with the exception of the skin, which still retains its original shape. But inside the skin everything is changed into a woody substance composed of a dense mass of fungus threads.

The natives of New Zealand, the Maoris, consider this "vegetable caterpillar" as great a delicacy as we do the common mushroom, and search for it just as eagerly.

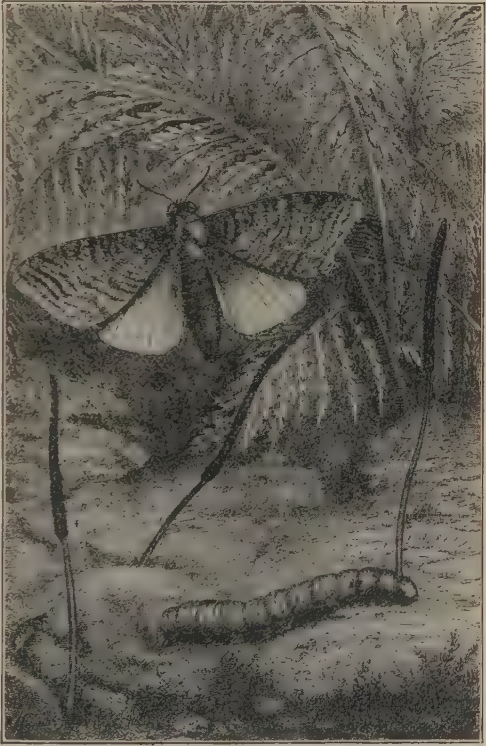


Fig. 65. The larva of a New Zealand moth attacked by a fungus

BACTERIA

It is possible to see with the unaided eye at least the spore-producing part of any fungus which we have already discussed. But the tiny fungus known as a *bacterium* can be seen only with the highest power of the compound microscope. If the bacteria cling together to form colonies, these are easily visible to the eye alone.

The bacteria include the smallest organisms in either the plant or the animal world. They are so small that it is difficult to appreciate their minute size. The following estimates may be useful in assisting the imagination. It would take 11,000 bacteria of average size, joined end to end, to reach across the centre of a new Canadian five-cent piece; or 190,066,800, placed side by side, to cover its area on one surface.

The majority of bacteria are one-celled, and, according to the shape of this cell, may be classified into three groups—spherical, straight rods, and spiral rods.

Bacteria are reproduced by the simple process of division known as *fission*. By this method a mature bacterium, or mother cell, forms two new daughter cells. Under favourable conditions, about thirty minutes are sufficient for a newly formed bacterium to reach maturity and become capable of division. At this rate, one of these germs in twenty-four hours would increase to the enormous number 281,474,976,710,656.

Since they are so small and increase so rapidly, we would expect bacteria to be widely distributed, and this is the case. They are found literally everywhere; the air, the water, and many soils are teeming with them. They survive extremes of heat and cold that would be fatal to any of the common plants. In the canning of fruit, care is taken to kill by cooking all microscopic forms of life, such as bacteria, yeasts, and moulds, after which the containers are sealed to prevent others from entering.

Although many of these innumerable bacteria are disease-producing, others are not harmful, and still others are essential to the continuance of life on the earth. Among the last are the species that produce decay in the dead bodies of plants. The bacteria decompose these or break them down into forms that can be used over again by other plants. Nature has only a certain amount of material at her command; it can never be increased or decreased; it can only be changed. How important it is then that this capital should be kept in circulation! Without the bacteria this would not be possible. The oak that has for many years been building into its body substances from the air and soil may, at length, be blown over. If the tree is allowed to remain, the bacteria will play a part in changing it into materials which plants can make use of again.

Among other changes that bacteria and yeasts bring about are those classed under the heading of fermentation. If cider is allowed to stand, it gradually turns to vinegar, as the bacteria change the sugar and alcohol in it to acetic acid (vinegar). The same agents cause milk to sour by turning the sugar in it to lactic acid. (See Figure 66.) In pasteurization, milk is heated to a sufficiently high temperature to kill all the disease-producing bacteria, but not all the acid-forming species. As a result of this, milk, although pasteurized, will still turn sour.

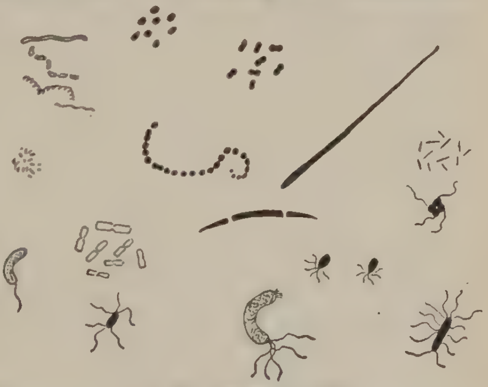


Fig. 66. Bacteria in milk

There are many diseases, such as typhoid fever, diphtheria, tuberculosis, influenza, and pneumonia, that are caused by bacteria. The effects are due, in the case of some of the diseases, to the poisons known as toxins produced by these germs. They are carried to other parts of the body in the blood currents, and increase the symptoms of the disease. In the body are often formed antitoxins that counteract or act as antidotes to the toxins. These antitoxins are now believed by the highest medical authorities to be bodies much smaller than bacteria themselves and are known as antibodies. If the antitoxins are produced in sufficient quantity, the patient will recover. The modern method of treating diphtheria is to assist nature by injecting a prepared antitoxin into the blood. Owing to the protective measures established by the body, a person who has once had a bacterial disease is not likely to contract it again. All bacterial diseases are infectious, as there is always a possibility of germs being transferred from a person suffering from the disease to a healthy person.

CHAPTER IX

GERMINATION OF SEEDS

The seed.—The seed is an embryo plant supplied with a quantity of food material. Most seeds can remain dormant for some time, in many cases for several years, but, under proper conditions of moisture, temperature, and food, they are capable of germinating and growing into plants similar to the parent plant.

There are two main types of seeds: (1) Those belonging to such plants as the bean, the wild mustard, the aster, etc., known as *dicotyledonous* seeds, and (2) those belonging to plants like the corn or the tulip, known as *monocotyledonous* seeds.

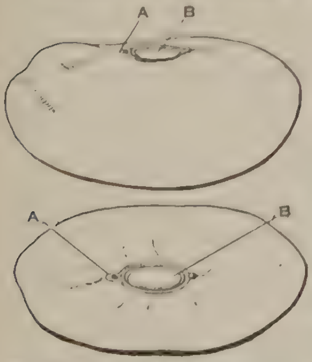


Fig. 67. The seed of the common bean before the seed-coats are removed. A, the micropyle; B, the scar

Parts of a dicotyledonous seed, such as the bean.—If bean seeds are soaked for several hours in warm water to soften them and are then examined, each will be seen to have several well marked features: (1) The *scar*, which lies on one edge of the seed and which was made by the attachment to the little stem in the fruit. (2) The micropyle, which is a minute opening near one end of the scar and which can be seen with a lens or located by exuding water when the seed is pressed. This little opening is probably the entrance by which water passes through the coats into the interior of the seed. (3) The *seed-coats*, which may be recognized by carefully slicing away the outside of a seed with a sharp knife. These consist of the outer coat, a somewhat thickened, tough, and often coloured layer, and the inner coat, which is much softer and is closely attached as an inner lining to the outer coat. These two coats correspond to the coats of the ovule, previously mentioned. (4) The *hypocotyl,* which, if the seed-coats are carefully removed, will be observed lying along the edge of the seed. (See Figure 68.) The tip of this hypocotyl rests close under the micropyle. (5) The *cotyledons,* which are two pieces lying flat together and making up the main bulk of the seed. These are found attached to the hypocotyl at its base. (6) The *plumule,* which is composed of two small leaf-like pieces pressed flat between the cotyledons and attached to the hypocotyl at the same point as the cotyledons.

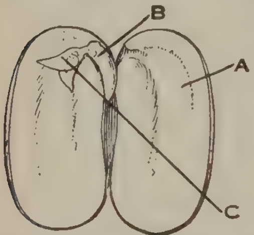


Fig. 68. The seed of the bean. A, a cotyledon; B, the hypocotyl; C, the plumule

The hypocotyl, the cotyledons, and the plumule constitute the embryo plant, as may be seen in the study of germinating seeds. The hypocotyl becomes the main plant stem, from which the root develops; the cotyledons are the first leaves, the so-called "seed-leaves," which are filled with food material for the young plant; and the plumule is the portion which gives rise to the upper part of the plant, its branches and leaves.

Parts of a monocotyledonous seed, such as corn.—The so-called corn seed is in reality a fruit called a grain, since it represents a complete carpel with ovary, style, stigma, and ovule. It is but one of the little pieces taken from the outside of the corn "cob," which is derived from the fertilization of many flowers crowded on a common axis. This is, therefore, a kind of multiple fruit. In the examination of this type of seed, we select the corn because it is larger than the seeds of most other monocotyledons, and its various parts are more easily seen. (See Figures 69 and 70.)

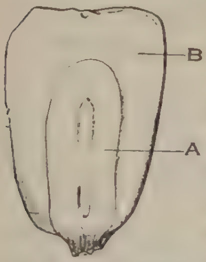


Fig. 69. A kernel of corn. A, the embryo; B, stored food

This seed consists of the following parts: (1) The scar, found at the bottom or inner end of the grain and representing the point where the ovary was broken away from the axis of the cob. (2) The skin, which is the covering corresponding to the wall of the ovary, fused with the seed-coats. (3) The proteid material, a food of yellowish colour filling the outer end of the seed and occupying the greater part of it. This is very hard and horny in the dry seed. (4) The starch, a food of lighter colour which is located in the centre of the grain. (5) The cotyledon, which, by splitting soaked seeds, may be seen sunken in the food material on one of the flat surfaces. This one cotyledon is a tongue-shaped piece which occupies about one-quarter of the seed. (6) The hypocotyl, a minute pointed body rolled up in the cotyledon toward the end next the scar. (7) The plumule, a rudimentary bud similarly rolled up in the upper end of the cotyledon and pointing in the opposite direction.

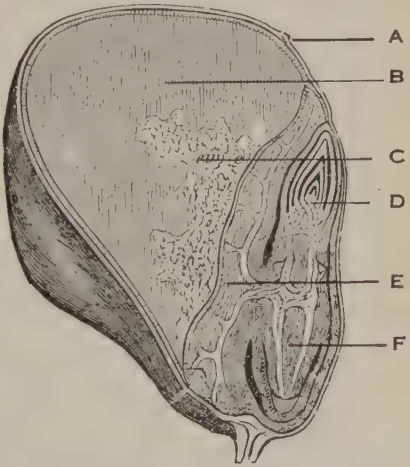


Fig. 70. A section of a corn fruit. A, the stigma; B, the yellowish-coloured food of the kernel; C, starch; D, the plumule; E, the single cotyledon; F, the hypocotyl

These last three parts again constitute an embryo plant.

Other seeds.—If other seeds, such as those of squash, horse-chestnut, peanut, and wheat, are examined in the same manner, they will be found to be very similar to either the bean or the corn seed.

The seeds of pine or spruce or other evergreen, however, differ somewhat. These seeds are so-called "naked" seeds, which lie on the inner face of the scale of a cone and have no outer covering of any kind, such as a pericarp. Each seed is also usually furnished with a thin wing. The pine seed has parts corresponding to those of the bean and the corn, but the embryo possesses several cotyledons. It, therefore, represents a third type of seed known as a *polycotyledonous* seed.

After fertilization, the egg gradually grows into an embryo or young plant. This reaches a certain stage of development and then becomes dormant. But it has the power of germinating or resuming growth when supplied with the proper conditions.

Some seeds, such as those of the willows and the grasses, are capable of germination as soon as mature. The majority of seeds, however, require a resting period after they are shed, before they will germinate. This resting stage varies greatly in length with different plants. The hawthorn requires about a year and a half, and some conifers, it is said, are incapable of germination for several years.

Although many seeds, such as those of the willows, lose their vitality unless germinated at once, others retain it for months and some even for years. At one time it was thought that the wheat and the peas found in Egyptian tombs and germinated were as old as the mummies. It is believed now, however, that the grains were not nearly so ancient as this, but had been placed in with the mummies at a very late date. Seeds have been taken from dated botanical specimens, and experiments carried out on their power of germination have shown that seeds may retain their vitality, in some cases, for eighty-seven years. Other experiments have indicated much longer periods of time, varying from 100 to 250 years. It has been found, also, that the seeds of the leguminous plants, including the clovers, the peas, and the beans, live the longest. Some of the mints and the water-lilies also produce long-lived seeds.

In order that a seed may germinate it must have warmth, water, and oxygen. Sphagnum moss, broken up fine, is probably the best substance in which to germinate seeds, but other materials, such as sawdust, sand, or earth, will serve the purpose. A good plan is to place the seeds between sheets of blotting-paper or pieces of flannel. In whatever way the seeds are planted, they must be kept moist, but not too wet. The supply of water is very important, as germination consists chiefly in the absorption of water by the seed and the consequent enlargement of all its parts. The temperature of the seeds should be kept as close as possible to 30° Centigrade, as this is the temperature which produces the best results for nearly all common seeds.

Germination of the common white bean.—We shall follow the successive stages in the germination of the common white bean and take them as typical of the process in a dicotyledonous seed. The first change that takes place in the bean seed is a very marked enlargement due to the absorption of water. This enters chiefly through the micropyle, but some also finds its way through the seed-coats. In a few days the root end of the hypocotyl may be seen forcing its way through the micropyle and rupturing the seed-coats. A root begins to develop from the hypocotyl almost as soon as it emerges from the seed-coats. This root grows downwards, sending out numerous rootlets and root hairs that serve to anchor it firmly. The lengthening of the hypocotyl causes it to appear as an arch above the soil. This arch is gradually straightened, as the cotyledons are withdrawn from the seed-coats and slowly elevated above the soil. The expansion of the plumule now becomes apparent by the elongation of its stem and the unfolding of its leaves. These are the first true leaves of the plant, since the cotyledons will shrivel and finally drop off as the food is absorbed from them. The parts above the soil and exposed to the light soon commence to turn green as chlorophyll is produced in them.

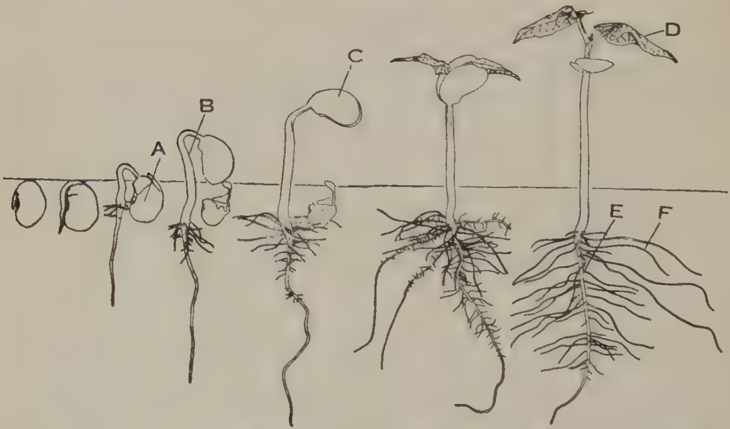


Fig. 71. Stages in the germination of the common bean. A, the seed-coat still retained; B, the bending of the hypocotyl; C, the cotyledon; D, a leaf from the plumule; E, a primary root; F, a secondary root

Germination of the acorn and the horse-chestnut.—The acorn and the horse-chestnut are dicotyledonous seeds that resemble each other very closely in their manner of germinating. In the former, the hypocotyl emerges at the small, sharp point on the nut. In the latter, it appears first at the edge of the scar. In both, the hypocotyl splits close to the cotyledons, disclosing the plumule. This, as germination progresses, gradually backs out of the cleft. As in the case of the bean, the root elongates from the end of the hypocotyl, and the plumule develops into the stem and the leaves of the plant.

Dicotyledonous seeds vary in their method of germination. In some the cotyledons remain below the soil, while in others they are carried up above it. Among the seeds whose cotyledons remain below the soil are those of the scarlet runner, the pea, the oak, and the horse-chestnut. The cotyledons of the squash seed are carried above the soil and spread out to form the first two leaves of the plant. In seeds like those of the squash and the maple, the plumule is slower in developing than in the seeds of the scarlet runner, the bean, or the pea, the cotyledons of which remain below the soil. When the cotyledons form leaves, there is, of course, not the same need of haste in the development of the plumule.

Germination of the corn or maize.—A kernel of corn or maize will serve to illustrate the germination of a monocotyledonous seed. The kernel of corn is really a fruit, but, as the pericarp is closely attached to the seed-coats, it has the appearance of a seed.

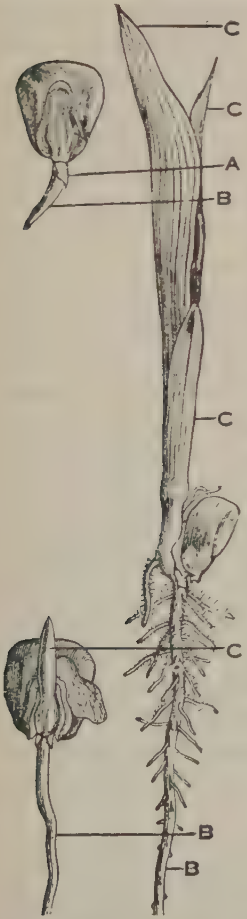


Fig. 72. Stages in the germination of the corn. A, the root sheath; B, a primary root; C, leaves

As in the bean seed, the primary root grows downwards into the soil, but other roots are soon produced from higher up on the hypocotyl. The result is a root fibrous in form. In contrast with the bean, the plumule of the corn is not pulled out of the soil, but pushes its way up. In order that its delicate leaves may not be injured in the process, they are sheathed around with older leaves. We have seen the cotyledons in the seed of the bean serving as storehouses of food for the young seedling, but the single cotyledon in the corn has an entirely different use. An examination of a corn kernel will show the cotyledon between the starchy food and the embryo. There it serves to absorb the food and pass it on to the embryo. But the cotyledon also changes the starch to sugar. This is a change similar to that which is produced by the action of the saliva on the starchy food in our mouths.

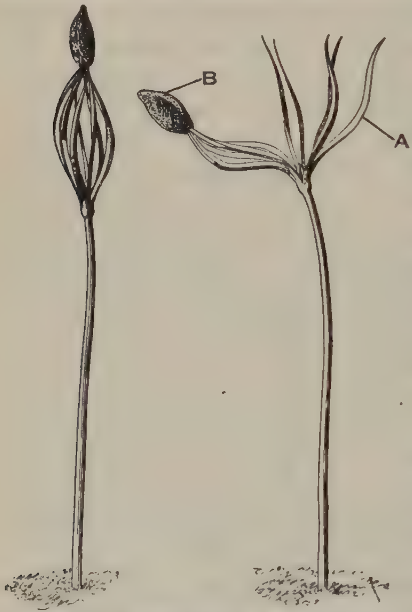


Fig. 73. The germination of the pine seed. A, one of the cotyledons; B, the seed-coat

Germination of the spruce seed.—In the germination of the spruce seed, the root grows downwards from the end of the hypocotyl, which forms an arch just as in the bean. Gradually this arching becomes straight, and the cotyledons inclosed in the seed-coats assume a vertical position. Then the cotyledons are withdrawn from the seed-coats, and the plumule soon begins to develop and expose its leaves. During the beginning of the second year the cotyledons drop off, all the food materials having been withdrawn from them.

The spruce seed is polycotyledonous, that is, it has more than two cotyledons, and in this respect the seeds of all other conifers resemble it. Seeds of the pine or the balsam will serve as well as the spruce for types of this class of germination.

EXPERIMENTS

Experiment 1.—Water is essential to the germination of seeds. Plant seeds in two separate boxes containing sand, sawdust, or earth. Water one box but not the other. Keep the two boxes under the same conditions in other respects.

Experiment 2.—Absorption of water through the micropyles of seeds. Seal the micropyles in a number of dry beans with sealing wax, plasticine, or other suitable material. After weighing the beans place them in water. At the same time place another lot of weighed beans in water, but do not seal the micropyles of these. After some hours wipe dry and weigh the sealed and unsealed beans.

Experiment 3.—Germinating seeds for class study. Line a straight lamp chimney completely with two or three sheets of blotting-paper. Shove a number of seeds in between the paper and the glass. Support the chimney in a vertical position with the end in water, so that the blotting-paper is in contact with the water.

Experiment 4.—Germinating seeds give off carbon dioxide. Place in a large jar, that can be tightly closed, a small beaker containing lime water. Fill the jar nearly as high as the top of the beaker with peas or beans that have been soaked in water. Close the jar and set aside until the seeds are well germinated. Note any change in the lime water.

As a check experiment, set up the apparatus as before, but omit the seeds. Set aside for the same length of time as in the former experiment.

Experiment 5.—Direction of growth of roots. Germinate seeds of the common bean until the hypocotyl is well developed. Plant these in earth, some with the hypocotyl pointing downwards, some with the hypocotyl upwards, and others with the hypocotyl pointing horizontally. After a few days examine them. Compare the effect of gravity on (1) the roots, (2) the rootlets.

Experiment 6.—Test for starch. Boil some water in a beaker and drop into it a small quantity of starch mixed with water, stirring well. Allow a drop of tincture of iodine (iodine dissolved in alcohol) to fall on a little of the prepared starch. Treat a small particle of the solid starch in the same way.

This reaction with iodine serves as a test for starch, even when present in small quantities.

Experiment 7.—Presence of starch in seeds. Soak a common bean seed and remove the seed-coats. Cut the cotyledons into thin slices and place these in a weak iodine solution. Examine under a low power of the microscope.

Practical Questions and Suggestions for Outdoor Work

1. During germination do the cotyledons of the following plants appear above ground or remain under ground: Maple, radish, wheat, beet, squash, cucumber, and lettuce?
2. Approximately how long is required for the germination of the following garden seeds: Beet, carrot, radish, lettuce, tomato, sweet pea, and petunia?
3. Why is it necessary to thin such garden plants as beets and carrots that are sown in rows?

CHAPTER X

GREEN LEAVES AND THEIR IMPORTANCE TO THE PLANT

Leaf structure and functions.—A typical leaf consists of an expanded part or *blade*, and a stalk or *petiole*, often with a pair of leaf-like organs attached to its base. As we wish now to discuss the functions of a leaf, it is necessary to know its structure more in detail. If we regard the leaf as a factory fitted to do certain classes of work, it is clear that, in order to understand the nature of this work, we must first know with what sort of machinery the leaf factory is equipped. This can be done only with the aid of very thin cross sections of a leaf, and a compound microscope.

Like all other parts of the plant, the leaf consists of a large number of inclosed spaces, which the botanists call *cells*. Each of these is surrounded by a wall, and so, in part at least, is separated from its neighbours. The cells are collected into groups that form definite parts of the leaf. The thin skin that can often be easily stripped off the upper or lower surface of a thick leaf is called the *epidermis*. Below the upper epidermis of the upper side of a leaf is a zone, usually of only one cell in thickness. Its cells stand close together, and from their resemblance to a stockade fence, when the leaf is cut across, this area has been named the *palisade* layer. Sharply contrasted with this is the remaining part of the leaf, the so-called *spongy* layer. Its thin-walled cells are irregularly placed, and many air spaces are left among them. (See Figure 74.)

A cell of the spongy, or palisade, layer may be taken as a typical plant cell (Fig. 75). In it, as in every cell, is a jelly-like substance—the wonderful and mysterious *protoplasm.* It composes the only living part of plants, as well as of animals, and from it all other constituents of these are built up. In this cell, the protoplasm forms only a thin lining to the walls, against which it is pressed by the *cell-sap.* This liquid, which occupies a central space in the cell, consists of water with sugar and other materials dissolved in it. In the lining of protoplasm are elliptical disk-shaped grains, containing *leaf-green* or chlorophyll. To these minute bodies is due the green colour of the leaves. As we shall see, the chorophyll plays a most important part in the life and work of the leaf. A rounded body consisting of denser protoplasm is present in all living cells. It is known as the *nucleus.*

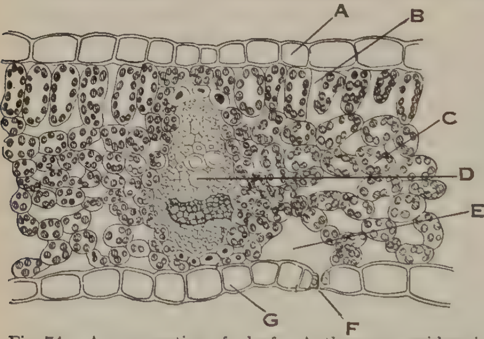


Fig. 74. A cross section of a leaf. A, the upper epidermis; B, the palisade layer; C, the spongy layer; D, a section of the midrib; E, an air space; F, a stoma; G, the lower epidermis

Like any other well-equipped factory, the leaf has entrances through which raw materials may be brought in and waste products carried out. The openings or *stomata* (Figures 76 and 77) that serve these purposes are in the epidermis of the leaf, each *stoma* or breathing-pore consisting of an opening bounded by two crescent-shaped cells called *guard cells.* These guard cells, by becoming more bent or by straightening out, open wider or make narrower the slit between them. Stomata are generally more abundant on the under surface of leaves, but in vertical leaves they appear equally on both surfaces. In leaves growing under water they are absent, and in floating leaves, such as those of the water-lily, they are found only on the upper surface. In addition to these stomata, which put the interior of the leaf into communication with the atmosphere, the leaf has veins, which connect it with all other parts of the plant.

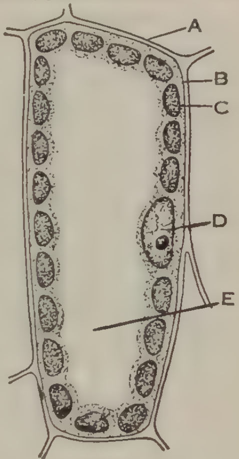


Fig. 75. A typical plant cell. A, the cell wall; B, the protoplasm; C, a body containing chlorophyll; D, the nucleus; E, the vacuole containing the cell-sap

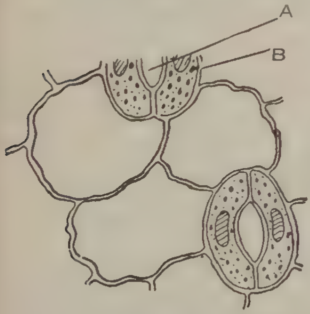


Fig. 76. A surface view of stomata. A, an opening through the epidermis; B, a guard cell

Knowing now the structure of the leaf, we are in a position to understand better the operations which it is fitted to carry out. One of the most important of these is the preparation of food for itself and the rest of the plant. This manufacturing or *photosynthesis* can be done only by green leaves, as it is carried on by the chlorophyll grains. To supply energy for the work, sunlight is necessary. The chlorophyll, therefore, may be regarded as a machine of which the source of power is light. Two common food products of this process are grape-sugar and starch, and the two simple materials with which the chlorophyll commences are water and carbonic acid gas (*carbon dioxide*). The water is collected from the soil by the root hairs and passed on into the roots. From there it is transported up the stem, and finally reaches all parts of the leaf by means of the veins. Carbonic acid gas is exhaled from the lungs of animals and is produced by the burning of such fuel as coal and wood. From these sources and from the plants themselves, as will be seen later, a supply is always available in the atmosphere. The air that has passed through the stomata reaches all parts of the spongy tissue by passing along the air spaces between its cells. The carbonic acid gas from this air penetrates the cell walls and reaches the chlorophyll grains, there meeting with the water brought in by the veins.

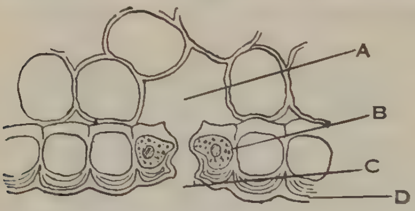


Fig. 77. A section of a stoma. A, an air space into which the stoma opens; B, a guard cell; C, an opening through the epidermis; D, the epidermis

A certain amount of the sugar manufactured for food by the leaves is slowly consumed, to supply the necessary energy that enables a plant to do its work. But this process, which is similar to combustion, requires oxygen, and this a plant must secure by the process of "breathing" or *respiration*. This work, too, is carried on by the leaf through the stomata.

As only a very small part of the water which enters the plant through the root hairs is used in the manufacture of plant food, the plant must get rid of a large excess of water. This giving off of water, which is known as *transpiration*, is also under the control of the leaves, the water passing off through their stomata in the form of vapour. The guard cells regulate, to a certain extent, this loss of moisture, widening the slits of the stomata in wet weather and narrowing them in dry weather.

Relation of leaves to light and air.—As we have seen, before chlorophyll can carry out its function of food manufacture (photosynthesis), it must be exposed to the light. The leaves, therefore, are usually arranged so as to have the most favourable light and, at the same time, the best exposure to the air.

There are several ways by which leaves secure these conditions. An examination of the vertical shoots of any of our alternate-leaved forest or orchard trees will show that a spiral arrangement of the leaves on the stem serves this purpose. On horizontal branches of many trees the petioles of the leaves are bent so as to arrange the leaves in two horizontal rows, one on each side of the branch. When the leaves have an opposite arrangement (Fig. 224), one pair is often placed at right angles to the pair below. In this way shading is prevented. The same effect is sometimes secured by the lower leaves having longer petioles than the upper leaves, to carry them out beyond the shaded area. This is exemplified in the maple and the horse-chestnut (Fig. 78). In most of the plants that have a rosette of radical leaves, these are arranged so that each leaf fits more or less accurately into the space between the other leaves, forming what is known as a *mosaic*. (See Figures 79 and 80.) This term is appropriate because, though often the leaves show very little overlapping,

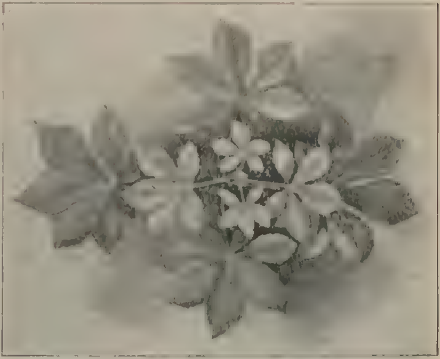


Fig. 78. Leaves of the horse-chestnut

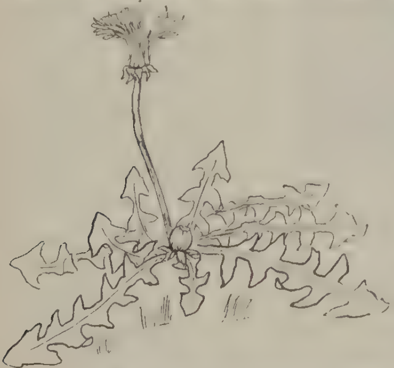


Fig. 79. A dandelion plant showing the rosette arrangement of the leaves

yet each fills its allotted space, just as do the pieces forming a mosaic pattern. Many plants, such as the carrot and the parsley, have leaves that are much cut and divided. This type of leaf is believed to secure suitable illumination without throwing too dense a shadow on the leaves below. The lengthening of the lower branches of trees is an important factor in securing requisite illumination for all the leaves. This growth of the lower limbs beyond the shade of the upper gives to many trees their tapering outlines. The proper amount of illumination is secured by the so-called "compass" plants in the following way: These plants grow with the edges of their leaves pointing approximately north and south, and the light from the mid-day sun falls directly only on the edges, but in the morning and evening, the sunlight, which is then less intense, strikes the fully exposed surface of the leaf. The prickly lettuce (*Lactuca scariola L.*), common in waste places, is an example of a compass plant found in Ontario.

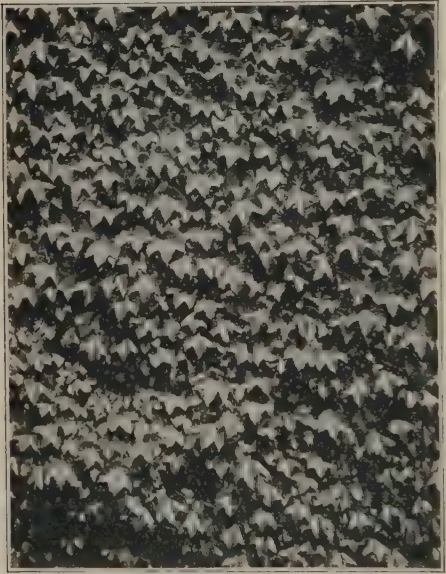


Fig. 80. The mosaic arrangement of the leaves of the Boston ivy

Longfellow refers in *Evangeline* to the compass plant (*Silphium laciniatum*) of the American prairies. It is stated by Sir John Lubbock, in *Flowers, Fruits, and Leaves,* that the poet's attention had been directed to the plant by General Alvord, who first mentioned its peculiar characteristics—

"Look at this delicate plant that lifts its head from the meadow,
See how its leaves all point to the north, as true as the magnet;
It is the compass-flower, that the finger of God has suspended
Here on its fragile stalk, to direct the traveller's journey
Over the sea-like, pathless, limitless waste of the desert."

Movement of plants.—The younger compound leaves of many plants, such as the clovers, the locusts, and the common bean, close at night and open again in the morning. The leaflets of some plants rise in closing, while those of others, such as the red clover, drop. The leaves of a number of other plants close when they are touched. A common example of these is the cultivated sensitive plant (*Mimosa*). Not only do the leaflets of this plant close on contact, but also the petioles of the leaves drop when touched. (See Figure 81.)

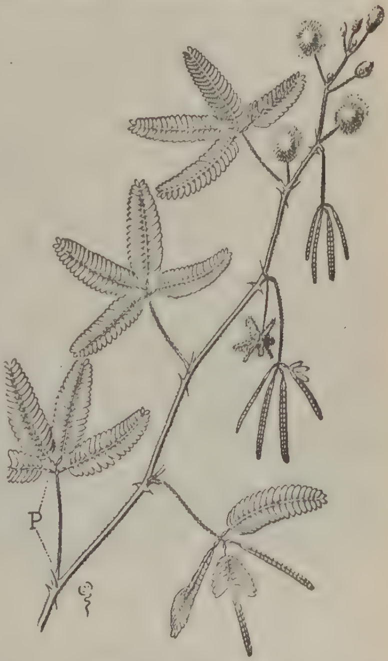


Fig. 81. Sensitive plant

The plant movements which we have just considered have no relation to increased starch production by the leaves, but there are other movements which clearly do assist in this process. It is a well-known fact that a plant placed in a window will turn until its leaves are facing the light (*heliotropism*). On account of this tendency to turn toward the light, our forest trees, such as the maple or the elm, are of two types. Those grown in the open have short trunks with limbs spreading widely in all directions, while those in the deep woods are the exact opposite, having comparatively long trunks with the limbs all at the top. The two types differ also in the position of their limbs. The sun type has almost horizontal limbs, while those of the shade type are nearly vertical. In both cases the limbs are growing in such a direction as to carry their leaves out into the light. (See Figure 83.)

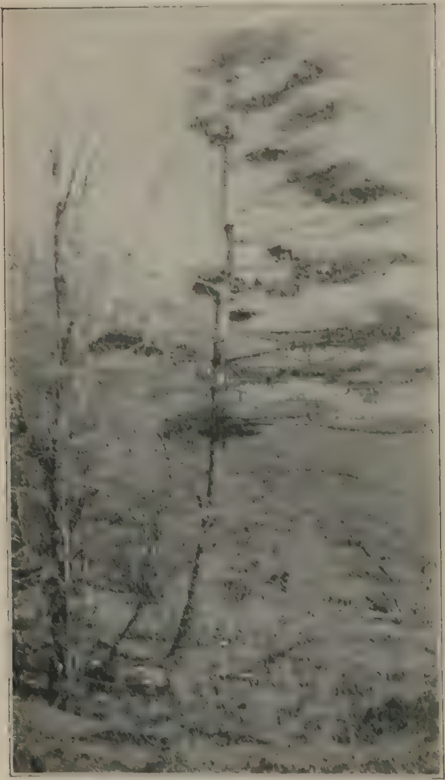


Fig. 82. Why are the branches of the pine better developed on one side than on the other?

Floral leaves, as well as foliage leaves, have movements in relation to light. The tulip and the dandelion, for example, close in the evening and open again the next morning.

Modified leaves.—Some leaves differ widely from that of the normal leaf which we have described. Such leaves are changed or modified to serve the plant in some special way. The barberry (Fig. 84) furnishes good examples of leaves modified into thorns or spiny points. In this plant the whole leaf is changed into a spine, but in the thistle only the veins of the leaves are extended out to form the spines.

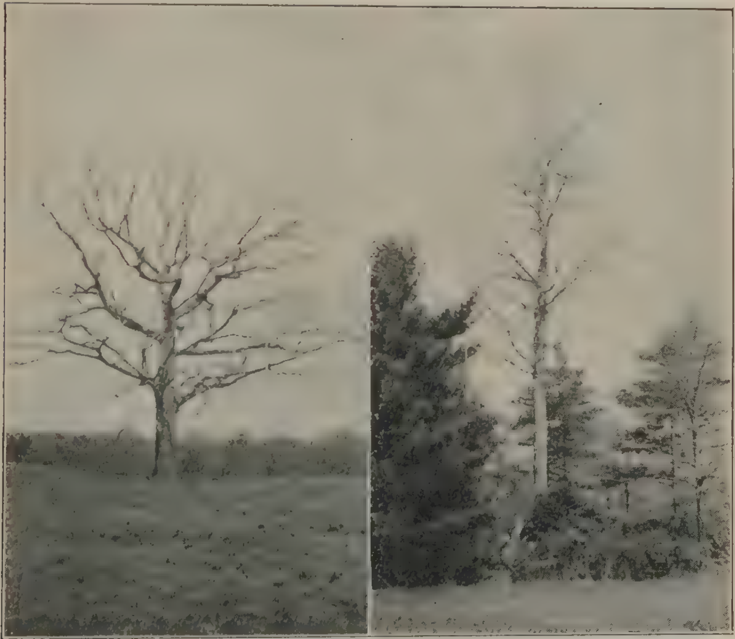


Fig. 83. The white oak. On the left is shown the sun type; on the right, the shade type.

It is commonly thought that spines on plants protect them from grazing animals, but recent observations have shown that the protective value of the spines has been much over-estimated. The compound leaf of the pea has its terminal leaflet modified into a tendril, a thread-like organ that has the peculiar characteristic of twining around any slim support with which it may happen to come in contact. The possession of tendrils gives plants the ability to climb. The clematis is an example of a climbing plant whose leaf petioles act as tendrils.

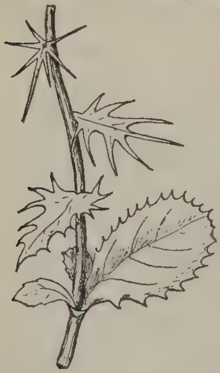


Fig. 84. A twig of the barberry, showing the spines

While most plants depend upon their leaves to manufacture their food, there are some plants which require animal food. Such plants are said to have insectivorous, or better, carnivorous habits. Their leaves are modified into cunningly devised traps to ensnare animals. The devices by which they catch their prey are of two classes. In one of these the snares are so constructed that, while entrance is so easy as to be almost involuntary, escape from them is impossible. In the other class the plant is more active in the work of destruction; the insect or other small victim is entangled and held fast by the movement of certain organs fitted for the purpose. In this case the trap is sprung when definite parts of the plant are touched.

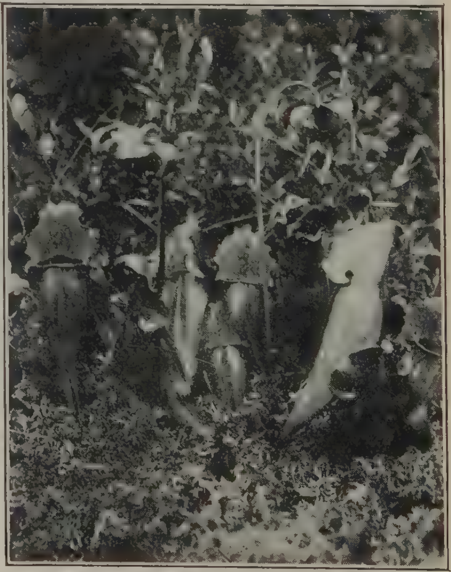


Fig. 85. Pitcher plant. This interesting plant is quite plentiful in our bogs.

The contrivance by which the familiar pitcher plants (Fig. 85) secure animal food furnishes an example of the first class of capturing apparatus. These plants are among the most abundant of our typical bog plants; they are seldom absent from any locality in Canada where peat mosses are growing. The traps, in this instance, are formed by the folding of the leaves into elongated, pitcher-shaped bodies. (See Figure 86.) Above the slightly contracted mouths of these bodies are the lips, which consist of expanded, concave, shell-like parts beautifully veined by reddish lines. It is probable that insects hovering about these pitchers are tempted to alight by the colours displayed, since to insects bright tints in flowers usually signify hidden stores of nectar. In this plant, however, not only is the landing place made perilously slippery by downward pointing hairs, but also the inside of the pitcher

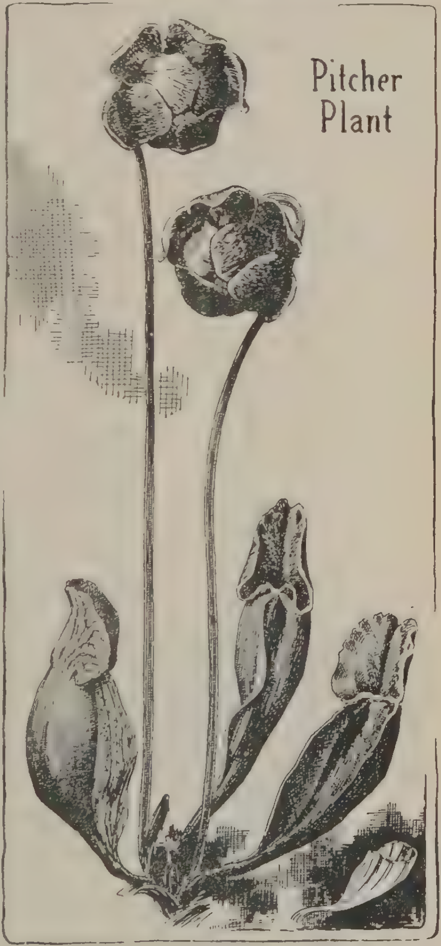


Fig. 86

is so smooth that not even the most sure-footed insects can cling to it. The result is always the same: they invariably slide down and drop into the water with which the pitchers are partially filled. With the flying insects in the trap are usually found a number of crawling species that have been caught. The fluid contained in the pitchers consists of rainwater, and in this the bodies of the insects decompose. As the resulting substances are absorbed, the plant is furnished with nitrogen-containing compounds that the bogs do not supply.

The pitcher plants secure their booty without being actively concerned in the taking of it. The sundews (Fig. 87), on the contrary, belong to the second class, in which it is necessary for the traps to be sprung and reset again by the movement of certain parts of the plants concerned. In our bogs two species of sundew are fairly common, but on account of their small size they are not often noticed. The leaves of both species have a covering of stiff, reddish hairs, from the tips of which a clear, thick liquid oozes out. When the little drops thus formed are sparkling in the sun like dew, the name of the plant appears particularly appropriate. Many insects alight or crawl upon the leaves, and there they are held fast by the gluey nature of the drops. Then,

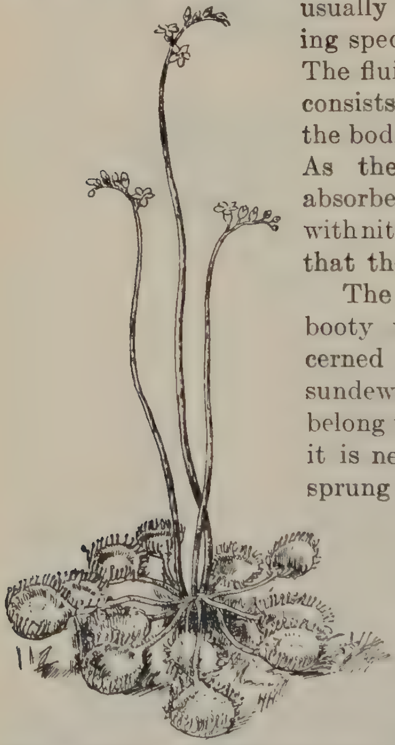


Fig. 87. Sundew. The leaves are ready to catch insects.

to make their capture doubly certain, the near-by hairs bend over and press the prisoners down until they are hopelessly entangled. This forcing down of the hairs upon the prey is accompanied by an increased flow of liquid from them, and the process of digestion at once commences. Only after all the juices of the insects have been absorbed do the hairs straighten up again. They are now swept clean of the undigested fragments by the wind, and the trap is ready for another victim.

The plant commonly known as Venus fly-trap (Fig. 88) is closely related to the sundews. It is not found within the Canadian boundaries, but grows wild only in the boggy parts of a narrow strip of territory extending along the Atlantic coast of the United States. It has an extremely clever device for capturing insects. The midrib of the leaf divides it into two somewhat semicircular lobes. Along the margin of these are numerous sharp teeth, the whole structure presenting the appearance of an old-fashioned rat-trap with jagged jaws. Along the centre of each lobe are three bristles, which, when touched, cause the two halves of the leaf to come quickly together. This effectually prevents the escape of whatever has sprung the trap. If the captive is capable of furnishing nourishment, a liquid is then poured over it by the plant, and the digested parts are absorbed. When nothing remains that is fit for food, the leaf slowly opens again, and the trap is reset.

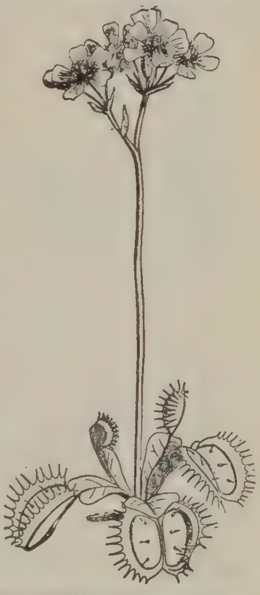


Fig. 88. Venus fly-trap, a plant which has developed an efficient insect trap

EXPERIMENTS TO ILLUSTRATE THE FUNCTIONS OF LEAVES

Experiment 1.—Light is necessary for the production of starch by green leaves. Place a plant in darkness for one or two days, so that the starch will disappear from the leaves. Then cover a part or the whole of some of the leaves with an opaque material to shut out the light, and expose the plant to the light for two or three hours. Remove the leaves that have been covered and some that have not been so treated. Boil these leaves in alcohol until as much as possible of the chlorophyll has been removed, and cover them with a weak solution of iodine. Note the result and explain.

NOTE.—A begonia or geranium plant answers well for this experiment.

To shut out the light from the leaves, thin sections of cork are often used. These may be cut from an ordinary cork and are easily held in place by a pin passed through the two sections and the leaf.

Experiment 2.—Chlorophyll necessary for starch-making. From a coleus plant select a leaf which is partly green and partly white in colour. Remove the chlorophyll as in the former Experiment. Test the leaf for starch. Make a drawing of the leaf, showing the area in which the starch is developed.

Experiment 3.—Green plants in sunlight give off oxygen. Place a water plant in a Florence flask completely filled with boiled water, as shown in Figure 89. Cork the flask with a stopper through which is passed a glass tube drawn out to a fine point. Invert the flask in the ring of a retort stand and place in the sunlight for a few days. Apply the oxygen test to the gas that accumulates in the top of the flask.

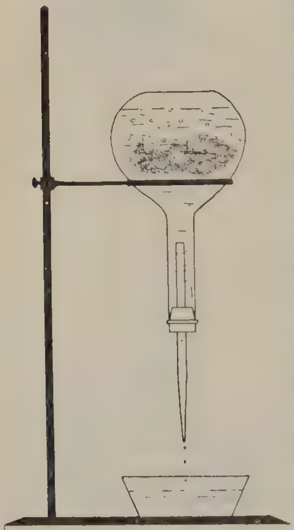


Fig. 89. Diagram to illustrate Experiment 3

There are several modifications of this experiment. The plant may be placed in a vessel containing water, and a funnel, provided with a tap, inverted over it. A large test tube may be used instead of the funnel, or a funnel and test tube may be combined as shown in Figure 90. Both funnel and test tube must be so placed as to be full of water at the commencement of the experiment.

NOTE.—Elodea, water milfoil, cabomba, or vallisneria are suitable plants for this experiment.

Experiment 4.—Water is given off from the leaves of plants. Prepare a plant by first watering it and tying over the top of the pot and around the stalk a thin sheet of rubber or oil-cloth. Place the plant under a dry bell jar for a short time, as shown in Figure 91. Moisture is soon visible on the inside of the bell jar.

As an alternative experiment, the plant may be placed on one pan of a balance with a counterpoise weight on the other pan.

Experiment 5.—The effect on a plant of too excessive transpiration. Place a potted plant in a very warm place and leave it for some time without water. After it begins to droop, move it to a cool place and water it well.

Experiment 6.—Demonstration of stomata. Strip a little of the lower epidermis from a leaf and mount it in water, under a cover glass. Examine with the low power of a microscope. Plants whose leaves are suitable for this purpose are: Tradescantia, lily, hepatica, and peony, or others from which the epidermis can be easily stripped.

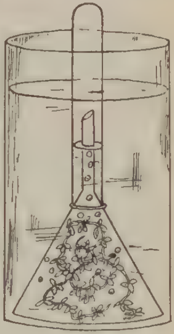


Fig. 90. Alternative apparatus for Experiment 3

Experiment 7.—Light is necessary for the formation of chlorophyll. Place some seedling bean plants in a dark room or cupboard, and others in sunlight. Note the plants as they develop.

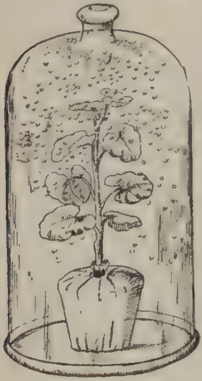


Fig. 91. Diagram to illustrate Experiment 4

PRACTICAL QUESTIONS AND SUGGESTIONS FOR OUTDOOR WORK

1. Describe the appearance of grass after it has been covered with a board for some days. What change takes place after the board has been removed for some days? What happens to grass left covered for some weeks? Try these experiments.

2. Describe the appearance of a potato plant grown from a tuber in a dark cellar. Describe and explain the appearance of a potato tuber growing partly out of the soil.

3. What effect is often noticed upon a leafy plant exposed at mid-day to the hot sun? What change has taken place in this plant by the evening of the same day? Explain.

4. Name some plants the buds of which serve as food for man.

5. Give reasons why trees and hedges in manufacturing towns and cities are not likely to thrive as well as those that grow in the country.

6. Why should celery be "banked"?

CHAPTER XI

STEMS AND THEIR FUNCTIONS

The stem is that part of a plant which is produced mainly from the plumule of a seedling. It tends to grow upwards toward the light, while a main root axis usually grows in the opposite direction, down into the ground. On the main stem and its branches, called secondary stems, are generally found leaves, buds, and often certain stem structures, such as hairs, spines, and thorns. At a certain season each year, they may also bear flower structures. Each stem and branch also, in most cases, terminates in a bud. Besides the usual stem type, there are other stem forms. Some are underground stems, for example, *rhizomes*, *tubers*, *bulbs*, and *corms*. (See Figures 217, 218, 219, 220, 221, and 222.) A few plants, like the cactus, possess green, flattened, leafless stems which have taken on also the functions of leaves. Others, such as the dandelion, have apparently no stem at all, the leaves appearing to grow from the top of the root.

If we examine the stems of plants, we find many covered with a separable bark, thick and somewhat roughened in trees and shrubs, but thinner and smoother in herbaceous plants like the buttercup. On the other hand, many, such as the corn, the bamboo, and the palm, are without this bark or skin and are usually quite smooth on the outside. If a stem of a plant of the first group, for example the branch of an oak, is cut across, there is seen on the cut surface a series of concentric rings about a central core or axis. On the other hand, a cut stem of a plant of the second group, such as the corn or the palm, reveals no rings. These two groups of plants are classed respectively as *dicotyledons* and *monocotyledons*. They show considerable difference in internal structure.

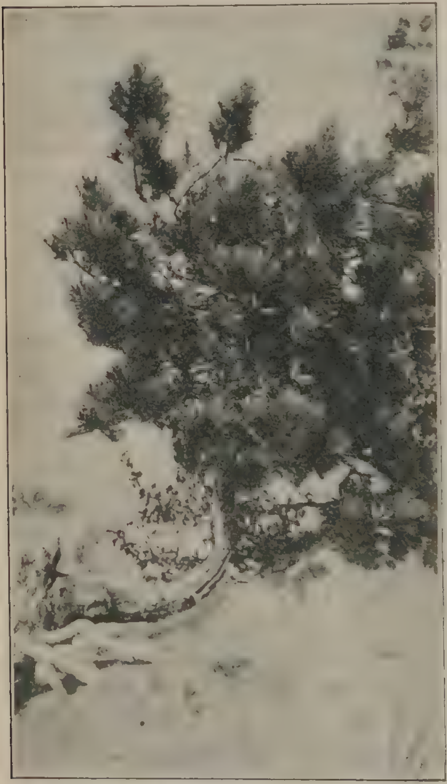


Fig. 92. This pine has fallen over but is doing its best to grow erect again.

Structure of a stem of a monocotyledon, such as the corn.— Thin slices or sections through a young corn stem (Fig. 93), examined with the low power of a compound microscope, show certain well defined groups of similar cells, called *tissues*.

1. Scattered throughout the stem are certain little dots or spots, more abundant and closer together toward the outside. If the section is parallel to the stem axis, these spots are seen as long strands or fibres, known as *fibro-vascular bundles*. They run lengthwise throughout the stem and branches and out into the leaves, in which they form the main veins. On closer examination, larger openings will be seen in these bundles. These represent the cut ends of long tubes or vessels. The function of these vessels is the conduction of water or sap from the roots to the leaves.

2. Besides these fibro-vascular bundles, there is seen a mass of thin-walled cells which fills up the stem around the bundles and is known as *fundamental* tissue.

3. Surrounding the stem is a superficial or surface layer of tissue called the epidermis. This is merely a protective covering.

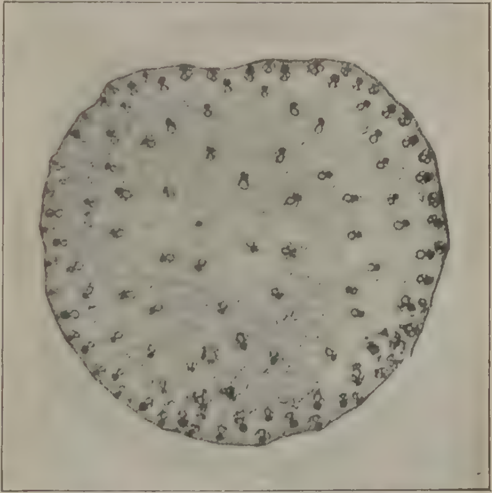


Fig. 93. A section of a corn stem, showing scattered bundles

Structure of a herbaceous stem of a dicotyledon, such as the buttercup or the sunflower.—An examination of transverse sections of a young buttercup or sunflower stem (Fig. 94) will show a somewhat different arrangement of tissues:

1. The series of bundles form a ring a short distance below the outer surface. This is the fibro-vascular ring.

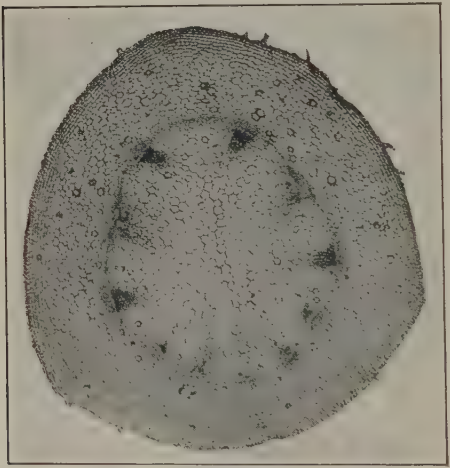
2. The central portion of the stem, within the ring, consists of thin-walled tissue. This is the *central cylinder* or *pith*.

3. A layer of thin-walled cells, called the *primary cortex*, surrounds the ring of bundles. This, with an outside layer of cells, corresponds to an outer bark.

4. A layer of thin-walled cells also passes between each adjacent pair of bundles and joins the cortex with the pith. It is from these layers that the *medullary rays* of a woody stem are derived. (See Figures 98 and 101.)

5. In older stems at least, the bundles are connected by a narrow line of rapidly dividing flat cells. These constitute the *cambium layer*. As this is continuous with a cambium inside the bundles, there is around the stem a complete ring of actively growing cells. From the cambium between the bundles the new bundles arise. And, as we shall see in the next section, it is this cambium ring which enables woody stems of trees and shrubs to grow in their characteristic manner.

6. Surrounding the outside of the stem is a single layer of cells with somewhat thickened outer cell walls, as in the case of the monocotyledonous stem. This forms the corresponding epidermis or protecting tissue.

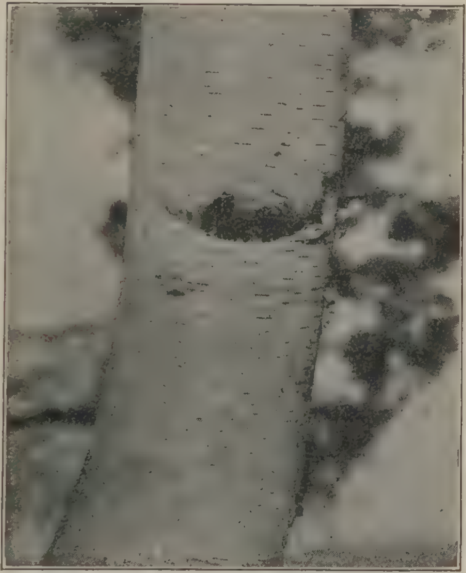


—*Courtesy of J. H. Faull, Toronto*

Fig. 94. A typical dicotyledonous stem, showing the ring of bundles and the cambium between them

Structure of a woody stem of a dicotyledon.—At first the structure of a dicotyledonous stem of this type is practically the same as that just described. However, as the stem continues its growth year after year, important changes develop. The epidermis and outer cortex, not being active growing tissues, are not able to keep pace with the growth within. As may be seen in young stems, they break or split open under the strain. Then there arises a new kind of tissue from the cells of the cortex. This is a rapidly dividing tissue in the outer cortex, somewhat resembling the cambium cells in the bundle and is known as *cork* cambium. From the outer cells of this cork cambium new cells are produced to form a tissue called cork. It is of this kind of tissue that the cork of commerce is made. It is obtained from a tree called cork oak, grown for its bark mainly in Spain, Portugal, and Northern Africa. It grows to a height of about thirty feet and may live to an age of 150 years. In eight or ten years the cork grows to a thickness of about two inches, when it is stripped off in sheets.

On tree trunks the cork forms an impervious layer of dead cells and is well adapted to serve as a protective tissue. Meanwhile, as the layers of cork cells increase, the epidermis and outer layers of cork split, and an outer rough bark is formed. This is the case in many woody stems, such as those of the oak, the maple, and the basswood. When the epidermis is ruptured, a further important change takes place. The stomata, which at first were present on it to admit air to the underlying tissues, are now replaced by lengthened openings, called *lenticels* (Fig. 95), which may be seen easily on stems of the elder or the birch. Below the



—*Courtesy of J. C. Doherty, Toronto*

Fig. 95. Lenticels on a paper birch

openings are formed cork cells which are grouped in such a way as to allow gases to pass in or out of the stem. (See Figures 96 and 97.)

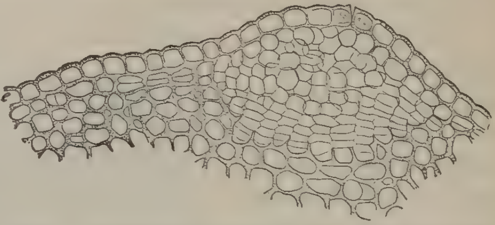


Fig. 96. The beginning of cork formation in the production of a lenticel

This cork tissue also serves the plant in other ways. It is developed rapidly around a wound caused by pruning or otherwise, gradually covering it. In the fall it forms a waterproof layer between the base of the leaf petiole and the plant stem, and, when the leaf drops, it serves as a protection over the resulting leaf scar.

The formation of cork, however, is not the only change that takes place in older stems. In stems two, three, or more years old, the wood has become divided off into concentric layers. These surround the central cylinder, which now forms in many stems a definite core called the pith. This is due to the fact that the cells of the cambium ring begin each season a new growth, developing on its outer side a new layer of soft inner bark known as *bast*, and on its inner side a new layer of wood. This layer surrounds the wood of the previous year. In this way the cambium advances, and the ring increases in size each year, thus shoving the bast farther outwards as it

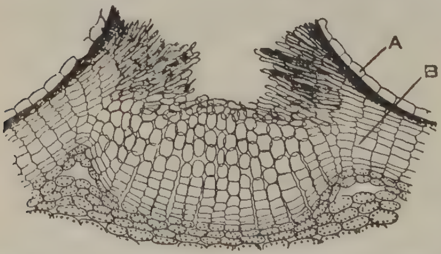


Fig. 97. The breaking open of the epidermis and the cork to form a lenticel. A, the epidermis; B, the cork

grows. Since the growth of the plant is most vigorous in the early spring season, the vessels formed in the new wood layer are larger, while toward the end of the growing season they become smaller, and the tissue in the wood grows finer in texture. (See Figure 101.) The following year the corresponding development of large vessels at the beginning and smaller vessels toward the end is repeated. The result of this is that in most woody stems distinct rings are thus marked out in the woody tissue. In the ordinary course of events, each of these rings represents a period of growth extending over one year, and the number of these annual rings seen in a stem cut transversely may be used to estimate, at least approximately, the age of the tree. For example, in the section of a stem of an oak tree, 300 rings would suggest that the approximate age is 300 years.

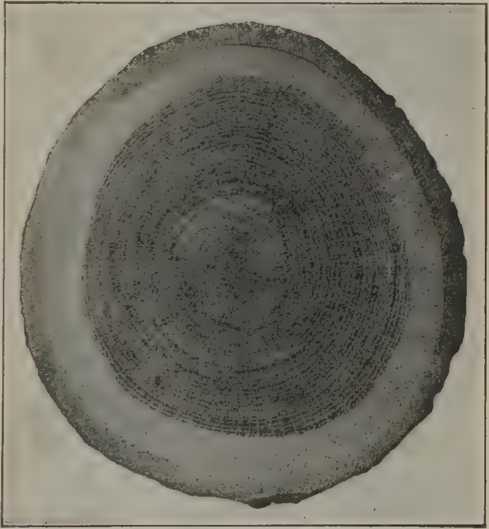


Fig. 98. A section of a woody stem, showing the bark, sap-wood, heart-wood, medullary rays, and annual rings of wood.

Heart-wood and sap-wood.—A section of the trunk of a red oak or a basswood several years old shows, in most cases, that the wood about the centre and for some distance out is dark and hard, while the outer newer layers are softer and much lighter in colour. (See Figure 98.) This newer outer wood is found to contain considerable sap and is therefore known as *sap-wood,* while the inner dark wood is known as *heart-wood.* The sap-wood is the part which conveys the sap from the roots to the leaves, and is, therefore, the part which furnishes the sap in the case of the sugar maple. In tapping a maple tree a hole is bored in a nearly horizontal direction well into the sap-wood. This hole must not extend into the heart-wood, as then the sap obtained is likely to make the syrup and the sugar too dark. Sap-wood which is sometimes seen on the edge of a board is not suitable for lumber, as it is filled with sap and is too soft. The experienced lumberman naturally prefers the harder, more durable heart-wood. But, although the heart-wood is more valuable commercially, the sap-wood is more useful to the tree, since through it water is carried to the leaves to furnish nourishment for the plant. Evidence of this is shown by the fact that, if a tree has the outer layers of soft tissue removed, it will be killed, but if the central heart-wood is destroyed, the hollow trunk may

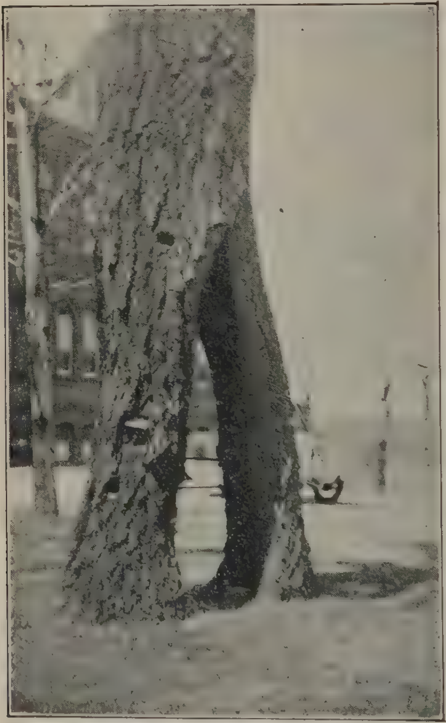


Fig. 99. A healthy oak tree, but the heart-wood has decayed away at the butt.

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still grow apparently with as much vigour as before. (See Figure 99.)

A further change in woody stems takes place in the thin-walled cells which stretch from the pith out between the adjacent bundles to the cortex. In the first year's growth the bundles are not close together. As the growth of the bundles advances, however, and new bundles are formed in the cambium ring, the thin-walled cells separating them are pressed into silvery lines or streaks, which radiate out in all directions from the pith and are known as medullary rays. (See Figure 101.) By making a vertical section through such a stem parallel to its axis, it will be found that these rays are not vertical sheets of tissue extending unbroken from the bottom of the stem to the top. They are merely thin, flattened shafts stretching outwards toward the circumference of the stem. These rays connect the different layers of wood, no doubt strengthening the stem and also acting as

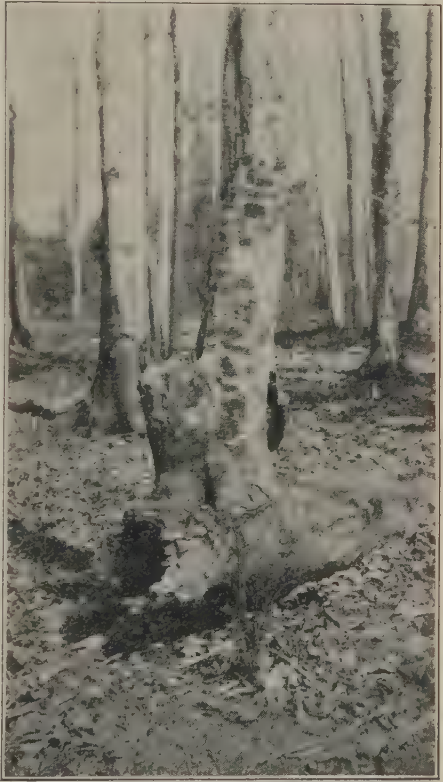


Fig. 100. A tree growing from a hollow log. Can you explain how this has occurred?

conductors of fluids between bark and pith. It is from them that quarter-cut oak lumber receives its characteristic appearance. Such lumber is cut as nearly as possible parallel to the rays.

Bark.—Bark is a characteristic tissue of woody stems. It may be defined as all that tissue lying outside the cambium ring of the bundles. It can, in most cases, be quite easily separated from the stem, particularly in spring, when the cambium is soft and juicy. This is done in the case of young stems of basswood or willow by the school-boy, who uses them for making whistles. For this purpose, the stem is first pounded lightly, so as to break up the cambium, making it possible to slip off the layer of bark.

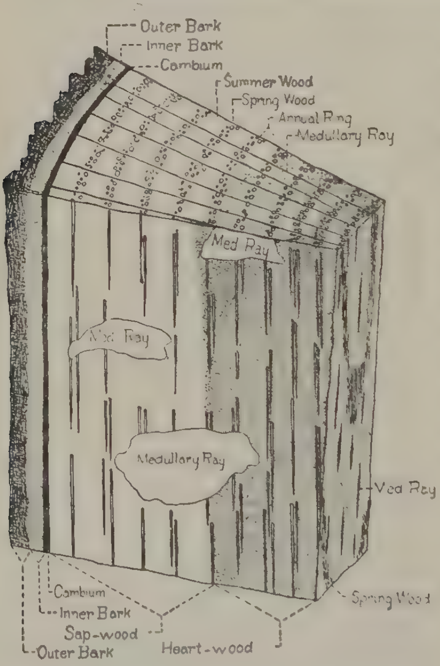


Fig. 101. Diagram illustrating the structure of a woody stem

The inner bark of a living tree is always green and active, due to the presence of chlorophyll and cell contents which enable it to assist in making starch for the sustenance of the tree. Through this layer the manufactured food is transported down the stems from the leaves. Consequently, a tree that is girdled (Fig. 102) will die, as food cannot reach the roots.

Functions of stems.—1. As already stated, the stems and branches of a plant serve as support for various outgrowths. By means of them the attached leaves are enabled to reach out on all sides to secure sufficient light and air for the manufacture of starch. The flowers are held some distance above the surface of the ground, so that they may carry on to better advantage their work of pollination, and the seeds are in a position more favourable for seed dispersal.

2. Stems, in many instances, afford protection for leaves, flowers, and buds, by the formation of thorns, spines, or glandular hairs. For example, the thorns on the hawthorn (Fig. 103), which consist of modified, much reduced branches, offer some protection from grazing animals. They are hard, sharp-pointed, often branched, sometimes several inches in length. The spines on the stems of the thistle and the wild rose serve a similar purpose, being developed mostly on the veins of the leaves and from the surface of the stems. And stinging hairs, such as on the nettles, warn the unwary against too close familiarity. Such hairs, tipped with a gland, secrete a fluid which when injected into the skin by the piercing hair produces a painful or stinging sensation.

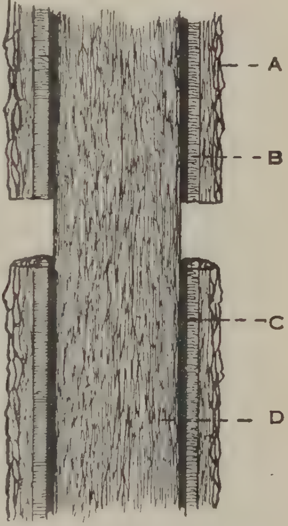


Fig. 102. Diagram to illustrate the girdling of a tree by the removal of the bark and cambium. A, outer bark; B, inner bark; C, cambium; D, wood. Water, as it is transferred by the wood, can pass the girdle, but the manufactured food, transferred by the inner bark, cannot pass the girdle.

3. Further, stems serve as receptacles for storing food during the cold season, when there is no growth. Underground stems, for example, particularly tubers, bulbs, and

corms, are rich in starch and other food materials. Also, many ordinary stems, such as the sugar maple, the birch, and the palm, contain a supply of sugar or starch. These foods are prepared and stored over winter in the plant in readiness for its growth the following season.

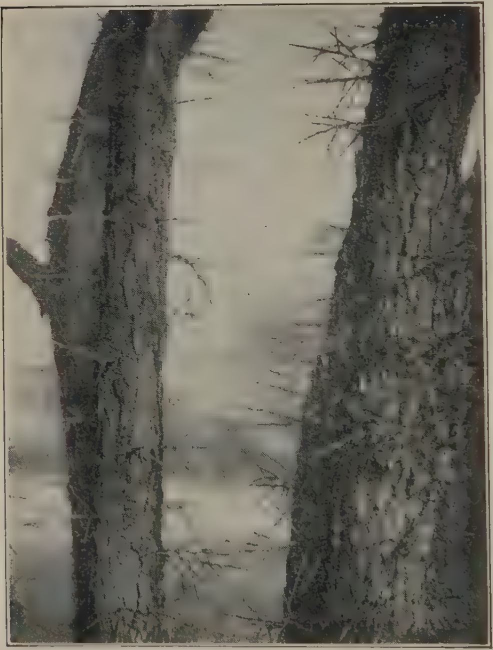


Fig. 103. A hawthorn, well protected by thorns

4. The conduction of sap and other food materials is perhaps the main function of the living parts of woody stems. As already stated, the large wood vessels carry to the leaves water absorbed from the soil by the roots. In the leaves some of this water is used up in the manufacture of starch. The food material manufactured by the leaves is then transported down the stem by the bast to places where growth is taking place.

Ascent of water in stems.—The rise of sap in the stem, sometimes to a height of 300 feet or more, is a phenomenon for which no entirely satisfactory explanation has as yet been offered. There are, however, several factors at work in the plant which appear to have at least some effect on this upward movement of water.

One of these is found in what is known as root pressure. (See pages 116 and 122.) This pressure is very marked in some plants, particularly in spring, and may reach two or three atmospheres. Such a pressure is sufficient to account for the fact that drops of water are often seen in the early morning on the leaves of grasses and other low plants, having been forced out through the stomata. After the water has been forced into the wood vessels by the root pressure, other forces no doubt help to make it rise still higher. One of these is the result of the rapid evaporation from the leaves of some of the absorbed water. This evaporation causes considerable diminution of pressure in the upper part of a tree, and the natural result is a further rise in the sap. Such a force is often termed *leaf-pull* or *leaf-suction.*

Still another factor has been suggested as playing an important part in this process—the force of *capillarity* or surface tension, a phenomenon well known in connection with capillary tubes. Since sap is carried by wood vessels which are very fine in bore, it seems possible that the force of capillarity would cause an additional rise in the sap. Some authorities even go so far as to say that this force alone is sufficient to lift it to the top of the highest tree. This is, however, not admitted by the majority, the general opinion being that the combined effect of all these forces is incapable of lifting the sap to such a height as it rises in some tropical and sub-tropical trees. Many other theories have been advanced by recent botanists who have discarded the above explanations. It must be admitted, however, that none satisfactorily explains this phenomenon.

EXPERIMENTS

Experiment 1.—To demonstrate passage of water. Place the cut end of the stem of a trillium, anemone, or other white flower in dilute red ink. After an hour or two, examine the floral leaves for traces of colour.

Note.—In this and the succeeding Experiment, cut the stems off under water to prevent air entering the vessels of the plant stems.

Experiment 2.—Experiment to show conduction. Use fresh cuttings of elder containing several leaves. Nearly fill a jar or bottle with water and colour it with a little red ink. In this place the cuttings, which have been cut under water so that air bubbles will not enter the vessel of the plant stems. Leave these in a warm room in a fairly light place for an hour. Examine the veins of the leaves for red colour. Cut the stems across at different intervals and split one of the stems. In what region of the stem is the red colour to be found?

Experiment 3.—Water passes through the woody part of the stem. Select a small leafy branch of a tree or shrub. Girdle its stem below the leaves, removing the bark. Place the cut end of the stem in water and leave for several days. Note if there is any effect on the leaves.

Experiment 4.—Presence of starch in tubers or other underground stems. Cut thin slices from a potato tuber and apply the iodine test for starch. (See Experiment 6, page 76.)

Practical Questions and Suggestions for Outdoor Work

1. In healing of scars made by cutting off limbs, does growth take place more rapidly from the sides or from the top and bottom of the wound? (See Figure 174.)

2. Name two plants in each case propagated (1) by bulbs, (2) by tubers, (3) by runners, (4) by roots.

3. Why do the cut ends of vines of the grape or branches of other plants "bleed" in early spring? Which cut surface bleeds the more freely, the one connected to the root end or the one connected to the branch cut off?

CHAPTER XII

ROOTS AND THEIR FUNCTIONS

Since there are several different classes of roots, it is difficult to give a definition that includes all of them. This being the case, we shall state only certain characteristics possessed by roots in general. In our germination experiments we have seen the primary roots invariably grow downwards, no matter in what position the seeds may have been placed. This tendency to grow toward the earth explains the fact that the roots of most of our plants are under the ground. These subterranean roots have their growing tips covered by protective *root caps.* (See Figure 104.) Roots have also the important property of collecting from the soil the water that is so necessary to a plant's welfare. Moreover, it is not water alone that is absorbed, but in it small quantities of dissolved materials which are essential to the healthy development of the plant.

Root structure (external).—Before the functions of roots can be understood, we must know something concerning their structure. Pull up a well-grown bean seedling and carefully wash the earth or sawdust from the roots. Most of the external characteristics of roots may be seen in this specimen. Unlike the stem, the root does not show nodes and internodes (Fig. 120), nor are its branches produced at regular intervals. The root is not perfectly straight, but, especially if grown in rather coarse soil, it has a number of bends in it. These have been produced because of the zigzag course which the root has followed in order to avoid obstacles. Examine the root carefully for buds and leaves.

Root cap.—In order to see this structure it will be necessary to look at the tip of a rootlet with a good lens or the low power of a microscope. (See Figure 104.) The name root cap is applied to it because the thin-walled cells that compose it form a cap-like covering for the tip of the rootlet. These cells are loose, and thus are rubbed off as the root is forced through the soil. They are, however, continually renewed from within. The root cap is a very important organ, protecting as it does the delicate growing region that is just behind it.

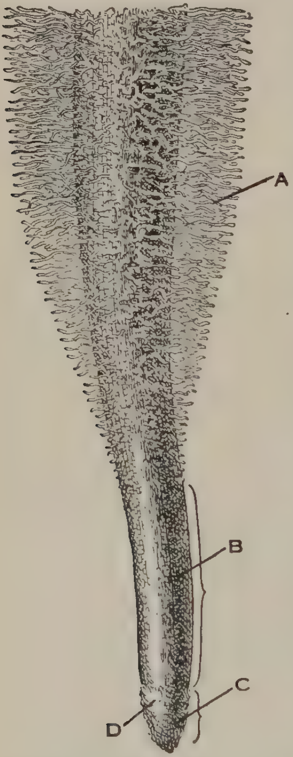


Fig. 104. A young root. A, root hairs; B, the region of elongation; C, the root cap; D, the growing point

Root hairs.—In pulling up the bean seedling, the root hairs will probably have been rubbed off. There are, however, several easy methods of germinating seeds so as to show them. Place seeds of turnip, radish, mustard, or timothy on damp filter paper placed on a plate covered by a bell jar, and leave for a few days in a dark room. Roots with many root hairs will soon be produced. A few seeds may be floated on water in a beaker, and the root hairs will soon develop. Other easy methods of demonstrating them are to germinate seeds between sheets of dark blotting-paper or to grow cuttings of such plants as willow, geranium, and wandering Jew in test tubes containing water.

Only a comparatively short portion (about 1 centimetre) at the tip of the root elongates. Back of this region, the zone of root hairs is developed. (See Figure 105.) It extends along the root for distances which vary with different plants and with the conditions under which they are growing. Can you give a reason why root hairs are not produced on the part of the root that elongates? At the front of the zone of root hairs new ones are continually being produced, but farther back they are dying at about the same rate. The result is that their total number remains approximately the same.

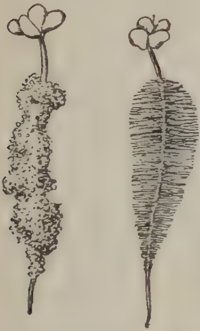
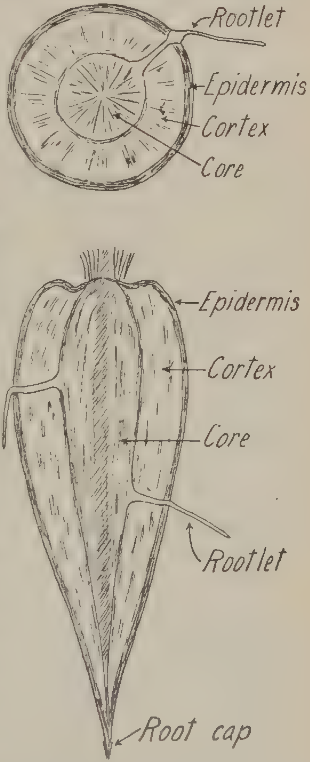


Fig. 105. Root hairs, with and without soil attached

You must think of root hairs as extremely slender closed tubes with frail walls. So inconspicuous are they that it is difficult to see a single root hair unless suspended in water or seen against a black background. As you will see if you examine root hairs under the low power of a microscope, they are outgrowths of the epidermal cells.



—*Courtesy of H. C. Andrews, Regina*

Fig. 106. A cross and a longitudinal section of a root (carrot)

Root structure (internal).—With a sharp knife cut lengthwise a carrot, which is a fleshy tap root, and examine one of the cut surfaces. You will see that in the root there is a cylinder at the centre, the so-called central cylinder, and surrounding it is a layer known as the cortex. The whole root is covered with an epidermis. Then cut the carrot across and pick out the central cylinder and cortex as before. These regions in the root correspond to the parts in the stem that bear the same names.

Although the stems of dicotyledons and monocotyledons differ greatly in structure, there is little difference between young roots of these two plants.

Soil.—Before you can understand how roots do their work, you should know how they are related to the soil and the water in it. The chief solid materials in the soil are gravel, sand, clay, and humus. The first three consist entirely of rock materials. They have been derived from the solid crust of the earth by various agents, such as the atmosphere, running water, moving ice, frost, and rain. Humus is made up of dark-coloured, decaying vegetable material. A soil is named from the constituent present in largest amount; thus we may have a clay soil, a sandy soil, etc. Besides the solid materials in the soil, there are substances dissolved in the soil water. These are present in relatively small amounts, forming less than one per cent of the total weight of the soil.

Soil water.—In the soil, water occurs in different relations to the soil particles.

1. It exists as very thin films around these particles, and is held so firmly by them that it can be driven off only as steam.

2. It occurs as thicker films about the soil particles, and, consequently, is not held so firmly.

3. It may trickle down freely between the soil particles.

These different classes of water are not all equally valuable to plants. Water of the first class is held so firmly by the soil particles that plants are not able to make use of it. Water of the second class, however, is more easily available, and furnishes nearly the whole supply for land plants. While water of the remaining class may be of indirect value to plants, as it sometimes provides a source from which the water used by plants is derived, it is usually detrimental to them, since it excludes air from the roots, and should be drained off.

As we shall see, capillary water is made more readily available for plants by being moved from particle to particle of the soil by surface tension or capillarity. This is the same force that causes the water to cling to the soil particles. The movement of this water in the soil is started by a soil particle which has not all the water that it can retain, attracting some from adjacent particles which are saturated. These, in their turn, will withdraw water from other particles, and so on. The result is that tiny currents are produced, creeping from particle to particle. In general these have an upward direction, since near the surface the particles are losing water by evaporation. Any other factor, however, that deprives particles of their water will start currents toward them. It may be that soil particles are surrounded by root hairs; if so, currents will be set up in that direction because the root hairs will absorb water from the particles of soil.

Cultivation of the soil.—It is a matter of common observation that after a shower of rain a sandy soil dries out more quickly than a clay soil. In general water soaks away more readily in a coarse-grained soil than in a fine-grained one. It may easily be seen, then, that since cultivation breaks up the particles it must increase the water-holding capacity of the soil.

Cultivation may also be directed toward decreasing the loss by evaporation of the capillary water, and thus increasing the total amount available for plant use. The loss of water brought up by surface tension or capillarity is very considerable, amounting to about one and one-third pounds per day from each square foot of ordinary farm soil. This loss can be largely prevented by closing, at the upper end, the very minute channels in the soil through which the water rises. That this is possible may be inferred from the damp soil found under stones and boards. In these instances the evaporation of the water carried up by surface tension has been prevented. In agriculture this loss is avoided by two general methods. By cultivating to a depth of a few inches, a layer is formed on the surface that checks evaporation, and the loosening of the soil prevents the water from rising by surface tension. The same results can be attained by covering the soil with a mulch of such materials as leaves, coarse hay, or straw, thus blocking up the capillary channels and preventing evaporation.

Cultivation of the soil gives the air free access to the roots of plants. Just how necessary such aeration is may be seen in the almost total failure of crops in fields that have been covered with water, even for a short time. When dams are built, the trees in the flooded areas soon die, since the water has shut off their supply of air. Roots of plants loosen the soil, making it porous and more easily penetrated both by air and by water.

Root functions.—1. *Anchorage and support.*—It is necessary for plants to be held in a favourable position to obtain air and sunlight. To provide anchorage is one of the chief functions of roots, since even the roots of germinating seedlings have quite a firm grip on the soil. On many of the rocky islands of our northern lakes, trees are often seen growing in locations where they can get only a very slight root-hold. Yet they are not blown over, although often exposed to high winds.

Further proof of the firm grip which roots have in the soil is seen in localities where there are stretches of "blow-sand." In such places it is a common practice to plant certain species of grasses whose roots tend to bind the sand particles together and make them less easily drifted by the wind. (See Figure 107.) It is stated by Curtis that the sand dunes would long ago have covered over the small town at the end of Cape Cod, if the drifting of the sand had not been checked by planting suitable sand-binding plants.

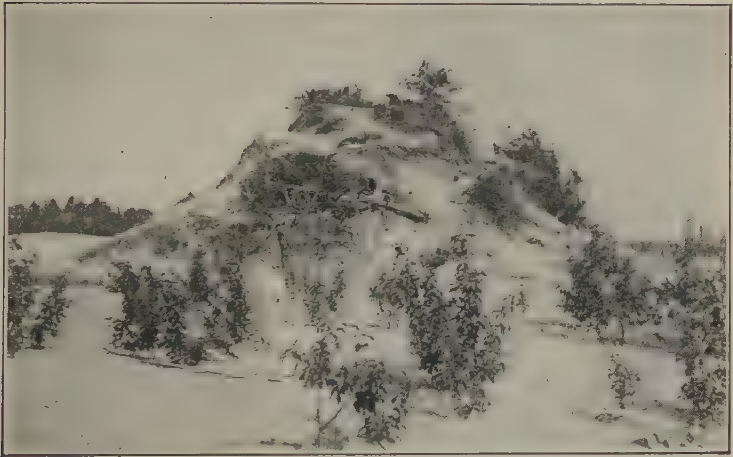


Fig. 107. A sand dune. The sand is held by the roots of the shrubs growing on the dune.

The supporting action of roots is well shown in the stalk of the corn. This is held firmly in place by roots that spring from the stalk well above the ground and grow downwards into it. In elms, maples, and other trees, roots near the surface of the ground often become so very much enlarged that they form buttresses against the trunks and so help to support them. (See Figure 108.)

The banyan and many other tropical trees develop strange supporting roots. They grow down from the horizontal branches of the trees and become rooted in the ground. These roots function as additional trunks and enable the tree to extend its branches farther. In Ceylon there is a banyan tree that has over 3000 such supporting roots. Beneath its shelter is a native village of one hundred huts. Many trees with prop roots, however, are not large, since the roots find difficulty in penetrating the hard soil beneath the trees. The banyan trees are regarded as sacred to Buddha and are cared for by his priests, who conduct the roots through bamboo rods to spots where the soil is kept well watered and cultivated.

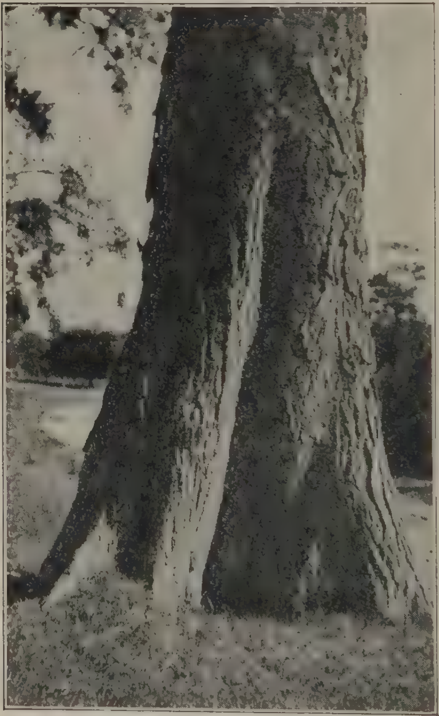


Fig. 108. Buttressed roots. The supporting action of these buttresses is important.

2. *Absorption.*—Another important function of roots is that of collecting from the soil the water that is so necessary to a plant's welfare. Nor is it water alone that is absorbed; dissolved in it are small quantities of materials essential to the healthy development of the plant. From the soil the plant thus draws compounds of nitrogen, phosphorus, sulphur, calcium, magnesium, iron, and potassium.

If any one of these is absent, the plant is not as vigorous in growth as it should be. For example, if iron is lacking, the leaves of the plants turn yellow; if the soil does not contain nitrogen, the plants are stunted. This information has been obtained by growing plants in distilled water to which has been added the proper quantities of these essential substances. Then other plants have been grown in solutions that lack each of these substances in turn, and a comparison has been made.

The water absorbed by the roots is essential to the plant for several reasons: (1) It is one of the materials required by the chlorophyll in the manufacture of sugar and starch. (2) It comprises over ninety per cent of the weight of nearly all herbaceous plants. (3) It keeps the cells of a plant rigid and in this way supports it. When the supply of water is cut off, the cells become soft, and the plant wilts. (4) It is required to dissolve the substances that are to be passed from one part of a plant to another.

The root hairs are chiefly responsible for the absorption of water by the roots, since the epidermal cells are capable of taking in very little. From the root hairs the water passes into the cells of the root and through them into the ducts or vessels of the wood. These carry it to all parts of the plant.

Water is absorbed through the walls of the root hairs and their protoplasmic lining by a process called *osmosis.* If a strong solution of sugar, or preferably molasses, is separated from pure water by a membrane, osmotic action is set up. After a short time, it will be found that water is passing through the membrane into the sugar solution, and some of the solution is passing the other way. This experiment illustrates the action of the root hairs. The sugar solution is in the hair, the water in the soil, and these are separated by a membrane composed of the cell wall and its lining of protoplasm. Just as in the Experiment, water passes into the sugar solution, but it is prevented from passing out into the soil water by the protoplasm lining the cell wall. In laboratories artificial root hairs have been constructed, which act in the same manner as the natural ones in holding back the sugar solution. If two sugar solutions of different strengths are separated by a membrane, the result is the same as before—the water passes toward the stronger solution.

Fig. 109. Food is often stored in thickened leaves.

The root hairs and the cells of the root drive the absorbed water, with its dissolved mineral substances, up the stems with a force known as root pressure. This pressure is often greater than that indicated on the barometer as the pressure of the atmosphere. If the branch of a tree or the stem of a grapevine is cut off in the spring before the buds have opened, water drips from the wounds. If the same experiment is tried in the summer, little or no "bleeding" occurs, since the leaves are giving off water by transpiration, and the pressure is reduced.

In order that plants may be supplied with sufficient water, their roots must spread over wide areas. This is especially true when the leaf-bearing part of the plant is extensive. In the oaks and the elms or other trees with spreading branches, the roots grow out on all sides to the limit of the branches. Interesting estimates have been made concerning the total length of certain roots, if all their rootlets were placed end to end. The rootlets of a corn plant, if so placed, have been estimated as extending nearly a quarter of a mile, while a squash vine has given a total length of fifteen miles.

Roots always grow in the right direction to reach water if there is any water near them. This explains the filling of drains and wells with the roots of such trees as willows, poplars, and soft maples. Often the roots of desert plants penetrate the soil to a depth of fifty or sixty feet in search of water.

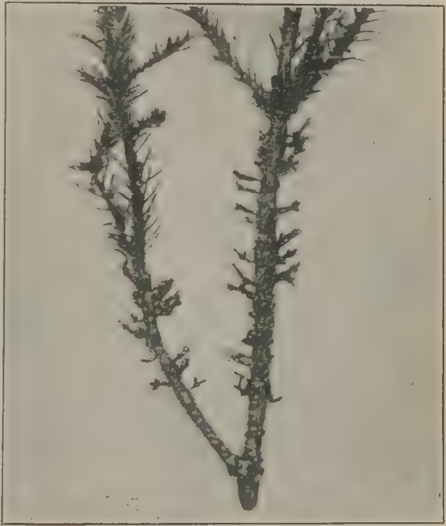


Fig. 110. Dwarf mistletoe. The tiny parasites are growing on a twig of spruce.

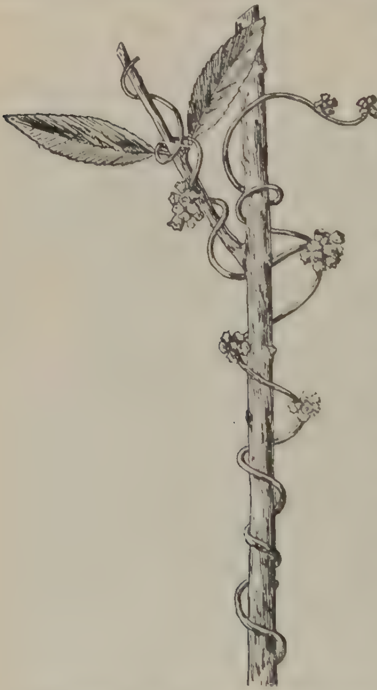
(3) *Storage.* — Although roots do not manufacture food, they often serve as store-houses for it. The best examples of this are furnished by the fleshy roots of such biennial plants as the turnip, the carrot, and the beet. These roots have food, as well as water, stored in them. In the beet a great deal of the storage food is sugar, while in the turnip it is chiefly starch. The food in such roots has been manufactured during the first year's growth of the plants, when leaves alone were produced. In the second year the stored food serves to nourish the plants when the flowers and seeds are being developed. Food is stored also

in fleshy leaves, such as those of cabbage, Brussels sprouts, celery, etc. (See Figure 109.)

Parasitic roots.—A parasitic plant is one that does not manufacture its own food, but obtains it from another living plant or animal known as the *host*. Some parasitic plants cling to the stems of their hosts, and obtain their food ready prepared by piercing these organs with root-like suckers.

The well-known mistletoe is not found on our oaks, but a closely related form, known as the dwarf mistletoe, grows on the branches of spruces in many parts of Ontario. The inactive habits of this plant have produced their inevitable results; and the parasite has become so dwarfed that only a careful examination of the spruce twigs reveals its scaly, olive-green stems. (See Figure 110.)

Another stem parasite, the dodder (Fig. 111), is quite conspicuous, owing to its long, reddish-yellow, string-like stems. Pauperism has caused this plant to degenerate so that its leaves are represented merely by a few minute scales, and the roots are present only at a very early stage of growth. Germination of the seed of the dodder takes place in the usual way, roots grow downward into the soil, and an



—Courtesy of United Church Publishing House, Toronto

Fig. 111. The dodder

erect stem soon appears above it. As soon, however, as this stem comes in contact with another plant, it coils around it for support and commences to absorb food from it. In a short time, the stem of the dodder breaks near the ground, and the parasite is entirely dependent upon its host for both food and water.

Some parasitic plants attach themselves to the roots of their hosts, and in this way gain access to their stored-up food. In this class are the beech-drops, the cancer-root, and the squaw-root.

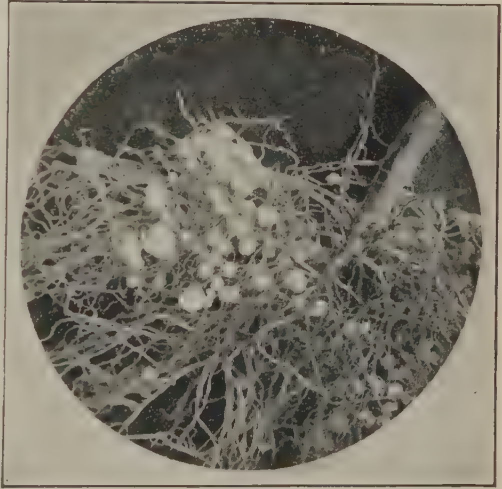
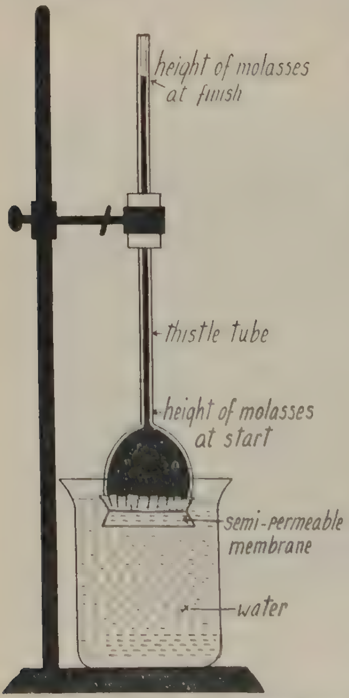


Fig. 112. Nitrogen-containing tubercles on the roots of a bean plant

Nitrogen-supplying roots. — Over every square mile of land there are approximately 20,000,000 tons of nitrogen, but this enormous supply can be used by plants only to a very limited extent. It is owing to the nitrogen-supplying roots that plants can utilize any of this nitrogen in the air. On these roots there are small swellings (*tubercles*) that contain very minute plants (bacteria). These are so small that they have gained access to the interior of the roots through the root hairs. The bacteria are able to combine nitrogen from the air with other elements to form substances that can be absorbed by the plants.

Only plants of the *Leguminosae Family*, such as clovers, peas, and beans, act as hosts for the "nitrogen-fixing" bacteria. (See Figure 112.) Since they obtain a great deal of their food supply direct from the air, such plants can be grown successfully on rather poor soil. When they are ploughed down as fertilizers, no other nitrogen need be added to the soil. Another very effective plan for introducing nitrogen into a soil is to sprinkle over it soil from a field where a good crop of nitrogen-fixing plants has been grown.



—*Courtesy of H. C. Andrews, Regina*

Fig. 113. Apparatus to illustrate osmosis

EXPERIMENTS

1. Experiments to illustrate osmosis. (1) Pour into a thistle tube sufficient concentrated sugar solution to fill the bulb and stem for a short distance. Tie securely a sheet of animal membrane or parchment over the mouth of the tube. Immerse the tube far enough in water to cover the membrane. (See Figure 113.)

(2) Reverse the experiment by pouring water into the tube and immersing it in sugar solution to the level of the water in the stem.

(3) Scrape a carrot lightly and hollow it out. Fill the cavity with concentrated sugar solution, and fit the opening with a cork through which a glass tube is passed. Seal around the cork with paraffin or sealing-wax. Immerse the carrot in water and set aside for two or three hours.

(4) Remove from the large end of an egg a piece of shell an inch or so in diameter. Take care not to injure the membrane lining the shell. Pass a glass tube into the egg through the small end. Seal around the

tube, where it enters the egg, with paraffin or other wax. Support the egg so that all the exposed membrane at the large end is in water. Leave the experiment set up for several hours.

(5.) Place dry raisins or prunes in water. Leave for some time and note results.

2. Experiments to illustrate surface tension or capillarity.— (1) Place in water the ends of capillary tubes with bores of different diameters. Such tubes can be easily made by heating glass tubing and drawing it out.

(2) Hold a cube of loaf sugar with its corner just touching the water in a beaker.

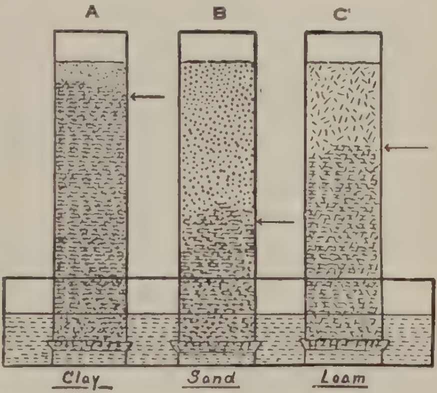


Fig. 114. Apparatus to test the rise of water in soils

(3) Substitute a sheet of blotting-paper for the cube of loaf sugar.

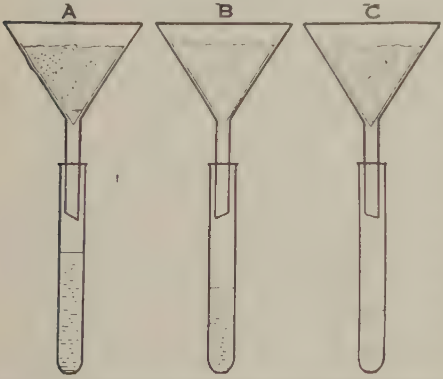


Fig. 115. Apparatus to test the water-holding capacity of soils

NOTE. — In the two preceding experiments a clearer result is obtained if a colouring material is dissolved in the water.

(4) Prepare several glass tubes by tying over one end of each a piece of muslin. The tubes should be about 30 centimetres in length and 2 to 3 centimetres in diameter. Collect different kinds of soil, such as clay, sand, etc. Take a sample of each and put it into a separate tube, nearly filling it. Settle the soil by tapping the tubes, and support them with their muslin-covered ends in water. (See Figure 114.)

(5) Half fill with samples of soil funnels lined with filter paper or

cheesecloth similar to those shown in Figure 115. Pour 50 cubic centimetres of water on the surface of the soil in each tube. Note the rate at which the water passes down through each soil. Collect the water that drips from the lower end of each tube. Find how much water has been retained by each soil. These amounts will give the relative water-holding capacity of each soil.

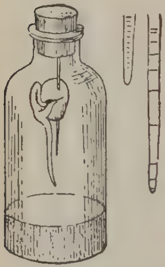


Fig. 116. Apparatus to locate the region of elongation of a root

Note.—Lamp chimneys answer well for tubes. The soils used in the two preceding experiments, should be slowly air-dried before being placed in the tubes.

3. Experiment to determine soluble materials in soils.—Take 3 or 4 grammes of different soils and boil each of them vigorously with water in a beaker. Filter and evaporate the filtrate to dryness.

4. Experiment to determine insoluble materials in soils.—Take on a knife blade a little of several different kinds of soils. Boil each sample with water in a beaker as before. Note if any material remains undissolved.

5. Experiment to locate region of elongation of a root.—Germinate a pea or bean until the primary root is approximately 2 centimetres in length. Commencing at the top of the root, mark off its whole length with cross lines in India ink, as shown in Figure 116. These lines should be about $1\frac{1}{2}$ millimetres apart, and care should be taken not to injure the root in drawing them. A very good plan is to mark the lines with a camel's-hair brush (or thread) dipped in India ink.

Select a wide-mouthed bottle fitted with a cork. Pin the seedling to the under side of the cork by passing a pin through a cotyledon. After partly filling the bottle with water to supply moisture, set it away in a warm place for two or three days.

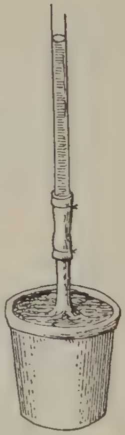


Fig. 117. Apparatus to demonstrate root pressure

6. Experiment to locate region of elongation of a stem.—For comparison, the hypocotyl and a part of the stem above the cotyledons of a well germinated bean may be marked off as in the preceding experiment. In this case the bean may be left where it is rooted.

7. **Experiment to demonstrate root pressure or sap pressure.**—Cut off a potted plant near the soil, leaving only an inch or two above it. (See Figure 117.) By means of a rubber connection, attach to the stump a straight piece of glass tubing about 80 centimetres in length. Pour into the tube a little water, and mark its level. Water the soil and stand away for a day in a warm place.

8. **Experiment to demonstrate root hairs.**—Line a large funnel with filter paper. Fill the funnel with sand. Plant seeds between the filter paper and the funnel. Watch through the glass the development of the root hairs.

Practical Questions and Suggestions for Outdoor Work

1. Name six plants that have food stored in underground stems. Name six plants that have food stored in roots.

2. What practical use is made of trees that have a powerful root anchorage?

3. Where should the fertilizer be placed about trees? Explain.

4. Why should soil in which seeds are to be planted be finely pulverized?

CHAPTER XIII

PREPARATION FOR WINTER

As our cold northern winter stops all the activities of plant life, our woods during that season resemble large industries with all their machinery in perfect running order but none of it in operation.

The supplies of prepared foods on hand are stored up at that season, awaiting the return of the active period of the plant's life, to be hurried from the centres of storage to those parts where growth has recommenced.

The woods.—Careful preparations are made by the woods for the winter period of low temperature and enforced inactivity. At its approach the trees and shrubs with delicate leaves shed these, thus enormously reducing the evaporation from the plants. The advantage of this is evident when we consider the lowering of temperature that results from the rapid evaporation of water sprinkled upon a floor or sprayed over the grass of a lawn.

The needle-shaped leaves of the evergreen conifers are retained throughout the year, but too rapid evaporation is prevented in them by their thick outer layers and by the small areas of surface which they expose to the air. If these leaves were not protected in this manner they would wither even before the temperature fell to the freezing point of water, because, at two or three degrees above that temperature the root hairs cease absorbing; and the water supply of the leaves would be shut off.

While the evergreen leaves are able to endure the severest winters, the reduction of the green surface which they can expose to the sun's rays has greatly lessened their efficiency as organs for the manufacture of plant food. On the other hand, this power of making food has been increased to the highest point of perfection in the widely expanded leaves that fall in the autumn.

Old age of leaves.—During the autumn the leaves of all our plants, except the conifers and a few other evergreens, are passing through their final stage of old age, with its waning vitality. Instead of the uniform greens of summer, reds and yellows are then the prevailing tints. The red represents a distinct change, with the formation of a new substance. The yellow material, however, has been present all the time, but becomes visible only when the vivid green of the chlorophyll has faded. Owing to worn equipment and the decrease in the power received from the sun, the leaf factory is no longer doing effective work and has to be discarded as scrap. But, in order that this may not entail a larger loss than is necessary, all the useful materials have been gradually removed from the leaves to the branches.

—Courtesy of J. C. Doherty, Toronto

Fig. 118. Witch-hazel. This plant is in blossom after the leaves fall.

The common belief that leaves break off from the branches because they are killed by the frost has been proved false. The plant is just as active in the shedding of its leaves as in budding them forth in the spring. A considerable time before the leaves have even started to change in colour, the plants have commenced their preparations for getting rid of them. During the summer a special layer of cells is formed across the leaf stalk, with the result that, by the time of leaf-fall, the leaf stalk is held to the branches by only a shallow layer of young cells. These cells have very thin walls and are soon changed into a mucilage-like substance that cannot support the weight of the leaf. The result is that a line of separation commences, which, widened by the wind or by water freezing in it, at length severs the leaf from the twig. Before the leaves fall, or immediately afterwards, the wound left by the dropping of the leaf is healed over by a thin growth of cork, which is perfectly waterproof. As this cork does not cover the ends of the bundle strands, these are plainly visible in the leaf scars.

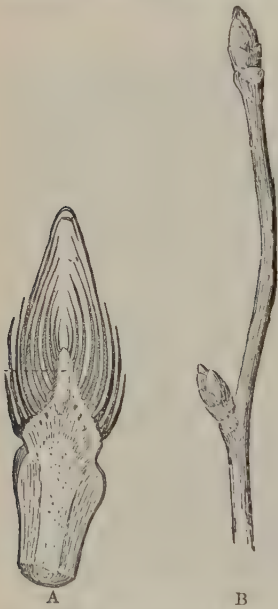
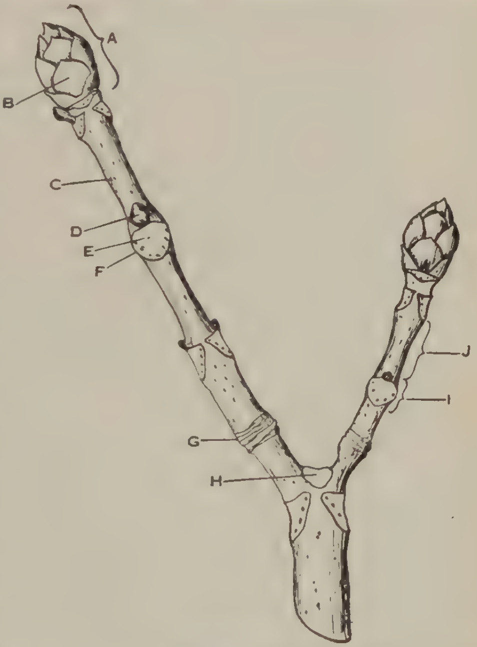


Fig. 119. A, a section of a bud; B, a twig with buds and bud scales

In addition to the preparations that will ensure the plants withstanding the low temperature of the winter season, the woods also prepare so that their activities may be promptly resumed upon the opening of spring. On most of our trees and shrubs the buds are formed during the growing season preceding that in which they are to burst forth into leaf.

Buds and bud scales.—A bud is an undeveloped stem and its leaves. The stem is very short, and the leaves are closely packed together. (See Figure 119.) The winter buds are covered with tough, leathery scales, which are often coated on the outside with a varnish-like substance. The young leaves are believed by some to be shielded from the cold by these bud scales. They, however, present too slight a barricade to keep the frost out, and ice crystals have been found in the interior of buds. The scales do, without doubt, prevent injury from too sudden changes in temperature, which may be caused by the alternate freezing and thawing weather of spring. Also, the resinous material that usually covers them is waterproof, and this serves the double purpose of preventing the loss of water by the buds and the soaking of water into them. Moreover, were it not for the scales, the tender, undeveloped leaves would frequently meet with injury from blows received when the branches are swayed by the wind. An effective device for the protection of the buds, apart from the bud scales, is found in the sycamore tree. There each bud is hidden in a little cavity at the base of the leaf stalk, and



—*Courtesy of Miss E. Ferguson, Toronto*

Fig. 120. A twig of the horse-chestnut. A, a terminal bud; B, a bud scale; C, a lenticel; D, an axillary bud; E, a leaf scar; G, bud scale scars; H, a fruit scar; I, a node; J, an internode

only after the leaf falls is the bud exposed. (See Figure 121.)

There are several different classes of buds:

Terminal buds are those that occur on the ends of the stems or branches.

Axillary buds are produced in the axils of leaves, with the arrangement to which they correspond.

Accessory buds.—If more than one bud occurs in each axil, the additional ones are termed *accessory*.

Adventitious buds are buds that are produced in unusual positions. (See Figure 123.) Poplars and willows invariably develop such buds when they are cut back.

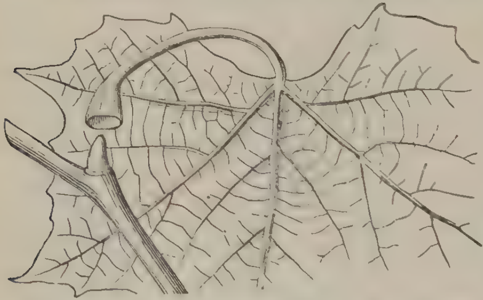


Fig. 121. A bud of the sycamore hidden in the base of a leaf petiole

Leaf and *flower buds*, as their names indicate, contain leaves and flowers respectively. Some types of buds contain both leaves and flowers.

Dormant buds.—It is not often that all the buds on a branch open in the spring; some of them remain *dormant* when the others leaf out. Many of these inactive buds are not developed until the killing of neighbouring buds places extra food supplies at their disposal.

As the buds are full-grown by winter, that season is the most favourable for seeing them. With no leaves to obstruct the view and against a background of snow, the long, beautifully tapering buds of the beech and the large glistening buds of the poplars stand out prominently. The largest buds on the willows, the alders, and the poplars are flower buds, and the catkins of these trees are always the heralds of the spring awakening.

This early opening of the buds is a distinct advantage in our northern woods, where the growing season is short. The ready response of such buds to warmth and moisture may be shown by bringing a willow or a poplar branch into a warm room during the winter and standing it in water. Soon the buds open, and flowers and leaves appear. In the early opening of its buds the red maple is a close rival of the alders and the willows. As the red colour of the bud scales gives them an additional power of absorbing heat, it is possible that this accounts, in part at least, for the red maple's early flowering.

When the buds are opening in the spring, it can be seen that the leaves in them have been folded in many ways, but always so as to take up the least space possible. (See Figures 124 and 125.) The young leaves of the beech and the maple are in fan-like folds; the plum leaf is rolled from one edge, and the violet from both. The well-known crozier or fiddle-head likeness of the sprouting fronds of the ferns is due to their unfolding from buds in which they have been rolled from the tips. (See Figure 138.)

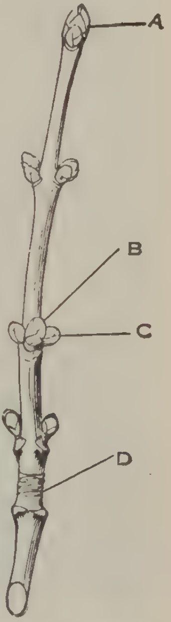


Fig. 122. A twig of red maple in winter condition. A, a terminal bud; B, an axillary bud; C, an accessory bud; D, bud scale scars

While this folding of the leaves permits them to be stowed away in a small space, it also protects them after they emerge from under the shelter of the bud scales. As they are not fully expanded at first, they do not at once meet the full glare of the sun, and thus have time to become accustomed to its heat. A thick covering of hairs often clothes the young leaves and prevents a too rapid loss of water from them. After the buds have opened and the bud scales have fallen, the marks of their attachment to the stem may be easily seen. As the bud scale scars last for many years, a history of the yearly growth in length of the stem may be read from these markings. (See Figure 120.)

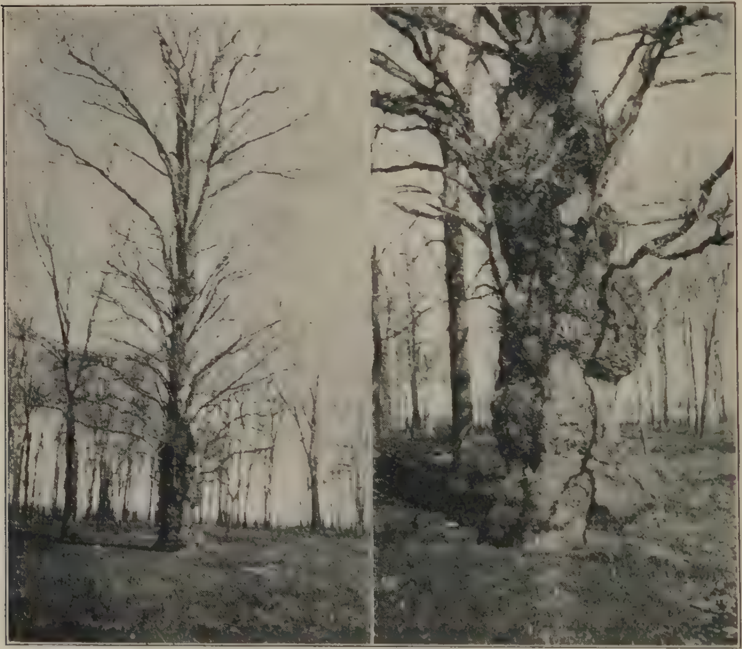


Fig. 123. A trunk of the bur oak deformed by the development of a large number of adventitious buds. The two illustrations are of the same tree.

It is a decided benefit to the small plants of the deep woods that they commence their growth early, as they can thus complete it before the foliage of the overshadowing trees shuts off the direct rays of the sun. Many plants, such as the trilliums, Solomon's seal, spring beauty, and others, prepare for this prompt response to the stimulus of spring by storing, in bulbs and rootstocks, supplies of sugars and starches that are available as soon as growth is possible.

Some plants pass the winter in the form of seeds. In others the seeds germinate and form small plants in the autumn. These rest throughout the winter, and continue their cycle of life to maturity in the succeeding year.

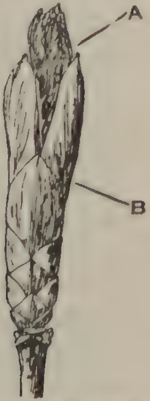


Fig. 124. A bud beginning to develop. A, leaves; B, bud scale

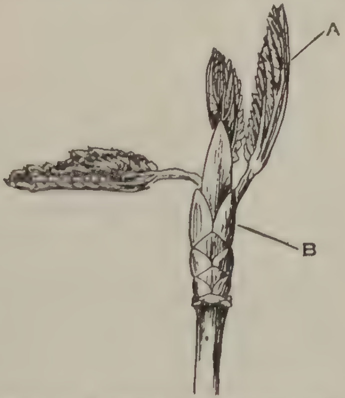


Fig. 125. A bud at a more advanced stage of development. A, a leaf; B, a bud scale

There are many points of interest to be discovered by the examination of any tree or shrub in our winter woods. Often a striking individuality is revealed by the manner in which each has prepared itself, not only to withstand the low temperature, but also to resume growth when conditions are again favourable.

Practical Questions and Suggestions for Outdoor Work

1. Name six early flowering cultivated plants that are reproduced from bulbs.

2. Explain why these plants come to maturity so early in the season.

CHAPTER XIV

WEEDS

What is a weed? We are so familiar with the burdocks, the thistles, and other plants commonly known as weeds that this seems at first sight an easy question to answer. But is it? When we try to select characteristics common to all weeds, difficulties arise. Furthermore, a plant may be a weed under certain conditions and a respectable member of plant society under others. Sweet clover, now recognized as a valuable fodder plant, is regarded as a most troublesome weed when growing along roads or in vacant lots. Buckwheat often comes up the next year after a crop of it has been harvested. These plants of the second year are classed as weeds. The brown-eyed Susan, the ox-eye daisy, and the bouncing bet of the gardens have

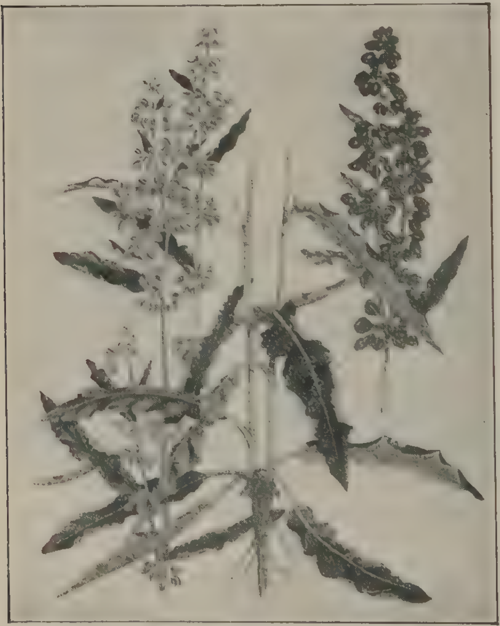


Fig. 126. Curled dock. This is a common weed in pastures.

escaped from cultivation and are running riot as weeds in the pastures and along the fence rows. June grass is encouraged to grow in the lawns, but is hoed out as a weed when it encroaches on the flower beds. The common mullein of our waste places (Fig. 127) is grown in English greenhouses under the name of the American velvet leaf. It would seem, therefore, that any plant growing where it is not wanted becomes a weed. Thoreau writes of toad-flax or butter and eggs: "It is called a troublesome weed. Flowers must not become too profuse and obtrusive, else they acquire the reputation as weeds."

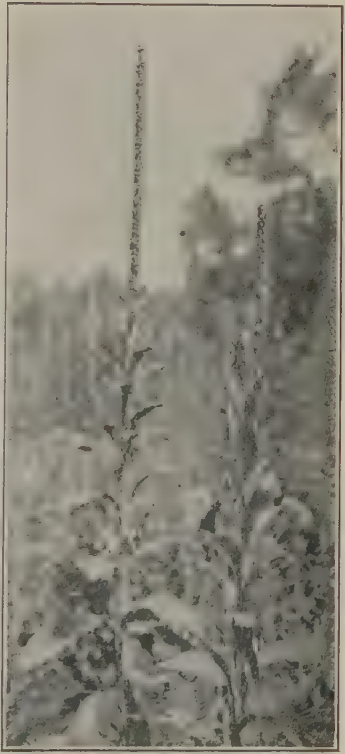


Fig. 127. The common mullein

Owing to the fact that Ontario was originally densely wooded, the vast majority of our native plants are shade lovers, and comparatively few of them have been able to adapt themselves to conditions in the open after the clearing away of the forests. In consequence of this inability to withstand exposure to the sun, most of our wild plants are disqualified as successful weeds. Our most serious pests of this class are those plants that have been introduced from other countries and have been able to establish themselves in the cultivated areas. Most of these undesirable immigrants are from Europe, but some have come from South America and Asia.

These introduced plants have been accustomed for so many generations to a life in the open that it is not a new experience for them to have to contest the possession of territory with cultivated crops. Indeed, the weeds brought into a new location generally prove even more injurious there, under the changed conditions, than they were in the countries from which they have come. When emigrating, they have usually left behind their insect and other enemies which served as a natural check on them. They have a further advantage, in that the mineral matter which they require has not been exhausted in the soil of their new homes to the same extent as in the old locations. The same principle that is operative in the rotation of crops is, consequently, working to their advantage.

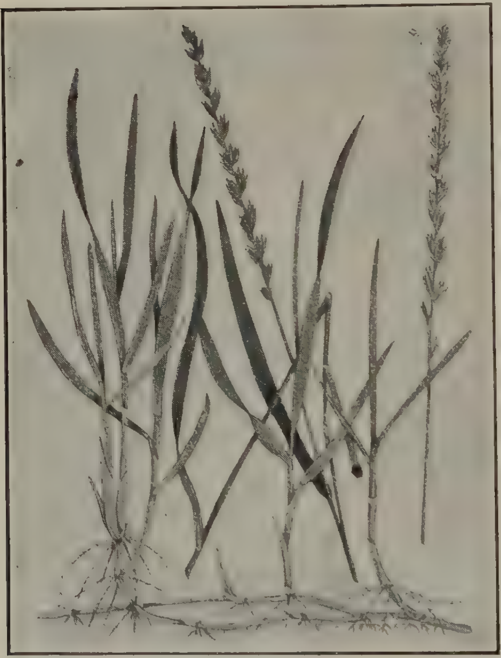


Fig. 128. Couch or quack grass. This weed is very difficult to eradicate.

Besides being able to withstand successfully the burning sun, the drought, and the dust of the open spaces, weeds must have other well marked characteristics if they are to wage a winning struggle for existence and crowd out the cultivated plants. Their seeds are always produced in large numbers. Each Russian thistle matures approximately 20,000 seeds, while the capsules on a single purslane plant have been estimated to contain as many as 1,250,000 seeds. When a single plant produces so many seeds, there must be some highly efficient method for scattering them, or the seedlings will have to establish themselves under conditions that are very much congested.

Distribution is accomplished, in the case of the Russian thistle (Fig. 130), by the wind rolling the plants over the ground, often far from their original sites, and thus sowing the seeds across a wide extent of territory. The Russian thistle's shape and habit of growth peculiarly adapt it to this plan of seed dispersal. Although it has very many widely spreading and much divided branches, these are curved outward so that they give to the whole plant a somewhat spherical form. The root is comparatively small, and in consequence furnishes a very insecure attach-

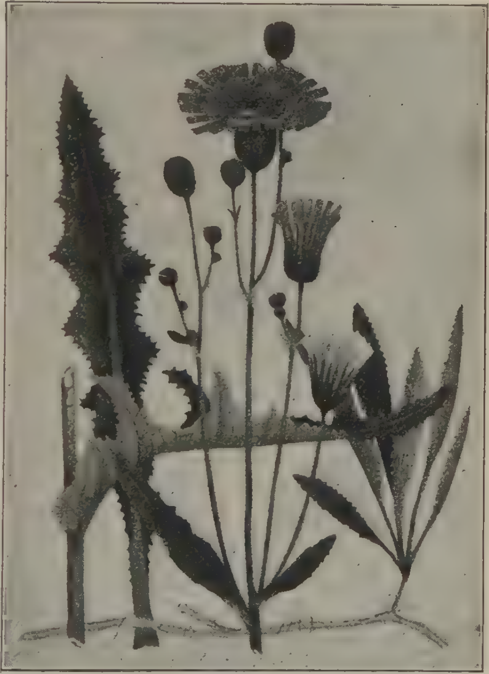
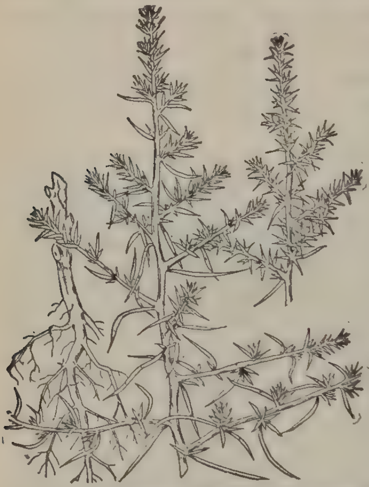


Fig. 129. The field sow-thistle. This is one of the worst weeds in the province. What are its means of spreading?

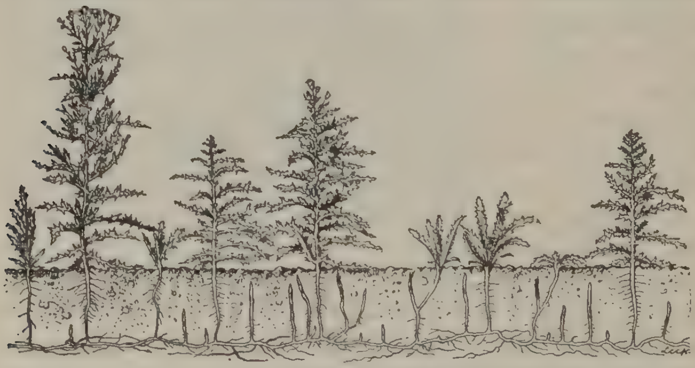


—*Courtesy of Seed Branch, Ottawa*

Fig. 130. The Russian thistle. Why is this weed not apt to spread very rapidly in Ontario?

ment to the soil. Toward the season's close, when the maturing of the seeds has made very large demands on the plant's supply of nourishment, the roots, shrunken from lack of food, are no longer able to hold the plant firmly anchored. As a result of this, it is torn from its moorings and carried away by the wind. In this way the Russian thistle, since its introduction into South Dakota, has rolled over an area of more than 25,000 square miles.

The seeds of some plants are so light that they are easily carried away by the wind; other heavier seeds are furnished with plumes, which ensure their being transported to great distances. Often the fruits of weed seeds are provided



—*Courtesy of The Grain Growers' Guide, Ltd., Winnipeg*

Fig. 131. The Canada thistle establishes new colonies by rootstocks.

with barbs and hooks, which attach them to the coats of sheep or other animals. In this way the seeds may be carried anywhere throughout the feeding grounds of these animals.

Weeds are often given wide distribution in ways other than by the dispersal of their seeds. Many of them colonize extended areas by means of underground stems. (See Figure 131.) These branch out from the parent plant, and, growing along a short distance below the surface of the soil, send up underground stems at frequent intervals. The bindweeds (Fig. 132) have creeping stems that have only to come in contact with the ground to produce roots. A plant which has this characteristic of reproducing itself so easily may spring from even a very short jointed piece of its stem.

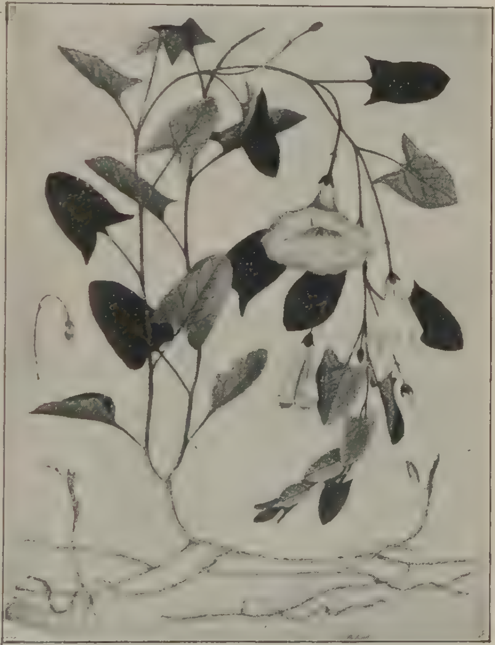


Fig. 132. The field bindweed. A beautiful plant, but it is a very serious pest.

There are different ways in which weed seeds may be carried from one country to another. The Russian thistle gained access to the United States in flaxseed shipped from Russia; and to the presence of foreign plant seeds in imported grains we owe the introduction of many other undesirable plant aliens. If the weed seeds are nearly the same size as the grain in which they occur, it is difficult to separate the two. For this reason corn cockle seeds can scarcely be screened out of wheat.

An historical instance of plant seeds carried in grain is that of the introduction of the field daisy along the route taken by General Sherman in his march across Georgia, "to the sea." The daisies that sprang up along the course of the invasion were produced from seed in the grain carried by the Northern forces to feed their horses.

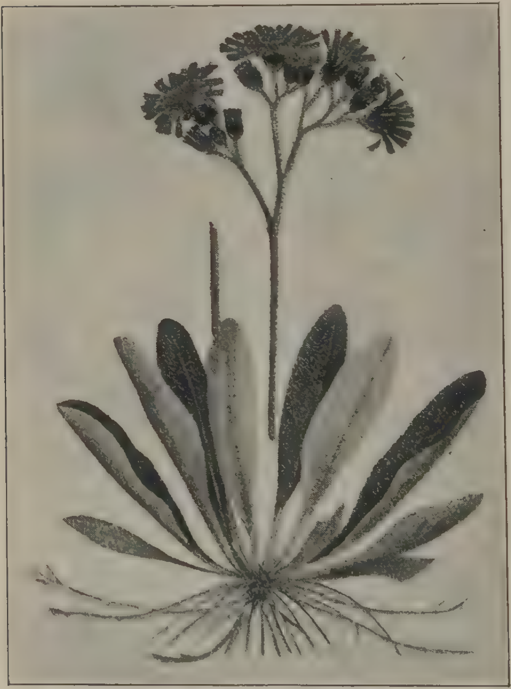


Fig. 133. Devil's paint brush. This weed is a pest, especially in the eastern part of Ontario.

Some plants, purposely imported, have become weeds. Among these are sweet clover, horse-radish, wild carrot, ox-eye daisy, and fuller's teasel. Fuller's teasel was introduced for use in fulling cloth. It was found that the spiny heads of this plant were better adapted for raising the nap than any artificial device. Since hooked seeds attach themselves readily to wool, carding factories act as centres from which weeds are spread. In this way the spiny clotbur was carried from South America to the town of Dundas, Ontario. It is stated that a patriotic Scot introduced Scotch thistles into his garden in California. These plants throve so well that the Scotch thistle is now a serious pest on the Pacific Coast almost from Alaska to Mexico.

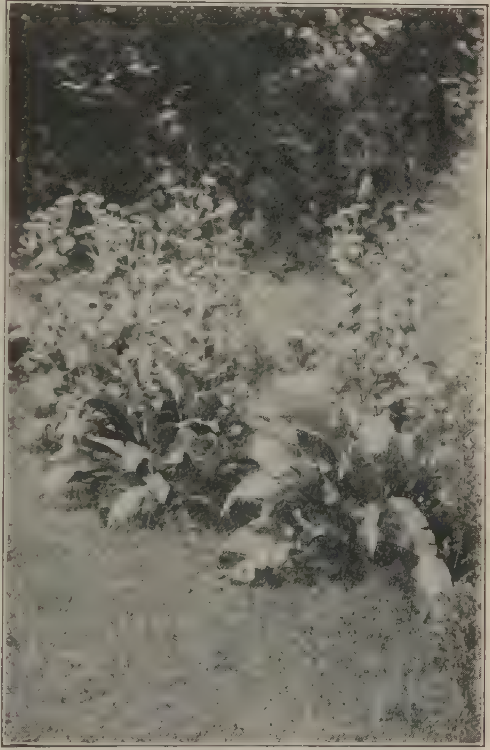


Fig. 134. Elecampane. This weed is not often very troublesome.

Weeds take a heavy toll of the crop production. Not only do their leaves and stems rob the crops of air and sunshine, but, also, their roots steal from the soil the nitrogen and mineral substances so essential to plant welfare. It is, however, in the absorption of water from the soil that weeds inflict their greatest injury on the crops. If weeds are plentiful in a field of grain, they will extract from the soil as much water as the grain. The result of this is, especially in a dry season, that the grain has not enough moisture and becomes thin and unhealthy-looking. This occurs, also, if the weeds are growing in hay or root-crops.

Weed control.—A great deal must be known about an enemy before it can be attacked successfully. This is true in the war of extermination continually being waged against weeds. The knowledge gained from a study of the weeds should be used in planning assaults on them.

Some of the more important questions to be answered concerning weeds are the following: What is the duration of the life of the weed? How does the weed take possession of new territory? If by means of rootstocks, how deep are these in the ground? If by seeds, how are these distributed?

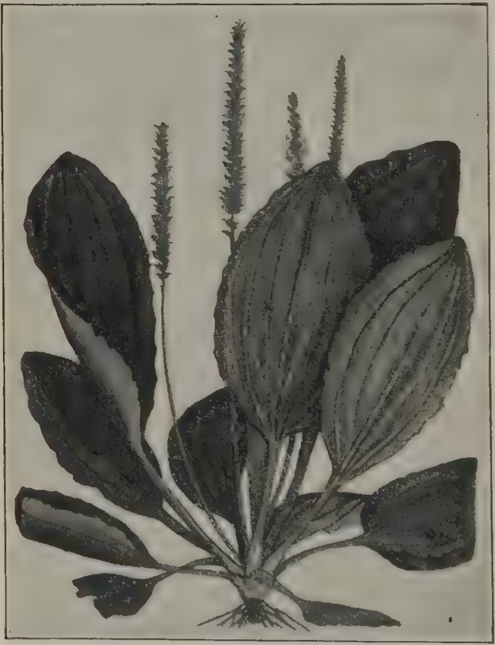


Fig. 135. Common plantain. If allowed to seed, this weed will spread quickly in a lawn.

There are a number of general principles adopted in the eradication of weeds. To exterminate an annual weed it is necessary only to prevent it from producing seed. If these are already in the soil, they should be induced to germinate, when the crop of young seedlings may be destroyed by ploughing them under. Seeds of some plants, unless brought near the surface by cultivation, will remain in the soil for many years without germinating. A perennial weed is not so easily conquered. A very good plan is to plough down the crop of seedlings in the spring. As the production of these has exhausted the stores of reserve food in the plants, the majority of them will die.

The modern method now generally used to clear the land of weeds is known as "short crop rotation." The best rotation for destroying weeds is one of three years' duration. It consists of a mixed crop of clover and hay and one of grain, separated by a year in which a hoed crop is grown. If the hoeing is done thoroughly, the land will be entirely cleared of weeds for the grain crop.

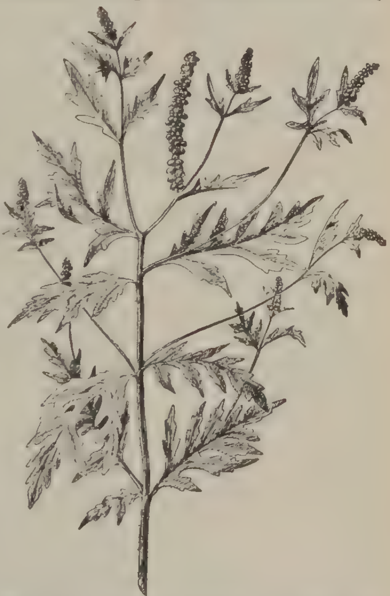


Fig. 136. Common ragweed, a weed that has been known in Ontario for many years

It must not be forgotten that in our war with the weeds we have valuable allies in several of our birds. Weed seeds form a large part of the winter food of such seed-eating birds as the juncos and the American goldfinches. The former are birds of the open spaces, finding their food in the weed patches along fence rows or about stone piles. When they are seen in the woods, flitting about in the underbrush, they frequent only the open places where sufficient light has been admitted to foster weed growth. The latter spend much of their time in the woods, picking seeds from the birch or the alder catkins or from the cones of the hemlock; but when the snow is not too deep they also often attack the weed beds in the clearings.

The goldfinches, however, seem to enjoy themselves thoroughly only when they find a thistle patch that is not snow-covered. It is not uncommon to see a flock of a dozen or more of these little birds enthusiastically tearing the fluffy heads to pieces. They cease their work scarcely for an instant, except to greet each other cheerfully with the sweet call-notes of midsummer.

The winter birds have keen appetites in the cold weather, and a great many seeds are required to furnish enough food for them. They consequently provide an important natural check on some of the worst of our weeds.

Practical Questions and Suggestions for Outdoor Work

1. Name four weeds of your district that are troublesome on account of their adhesive fruits.
2. Name four common weeds the seeds of which are scattered by the wind.
3. Name four weeds that propagate by rootstocks.
4. Name three troublesome garden weeds and state a common method of eradicating each.

CHAPTER XV

FERNS

In number of species this group of plants is a relatively small one. In Ontario approximately fifty species have been identified and described. Ferns are greatly admired because of their attractive feathery foliage and graceful habits. On account of their size and ease of culture they are familiar objects in the home and the garden. Many species are native to shady roadsides and rocky hillsides. Some, on account of their spicy odours and sober green foliage, furnish the main attraction of the summer woodland. A few, not so well known perhaps, find their abode in crevices and cracks of limestone cliffs.

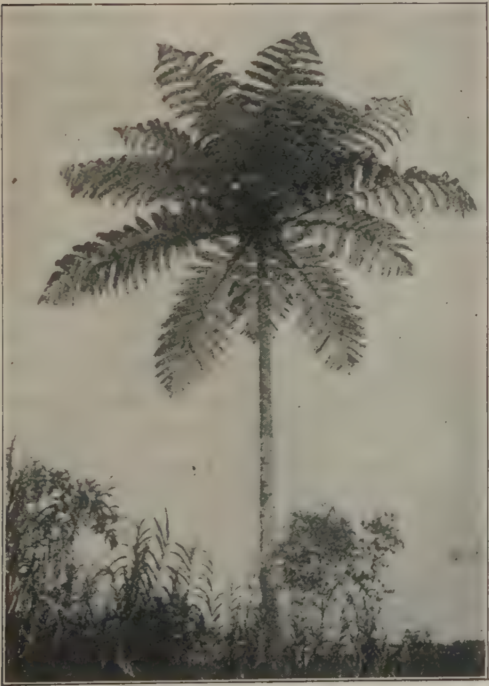


Fig. 137. A tree fern. The tropical ferns often grow to a height of forty feet.

Ferns thrive only under suitable conditions of warmth, moisture, and shade. They also require a proper supply of decaying humus or vegetable material in the soil. Under such conditions the student of botany may secure and keep close at hand for observation and study almost any of our native ferns.

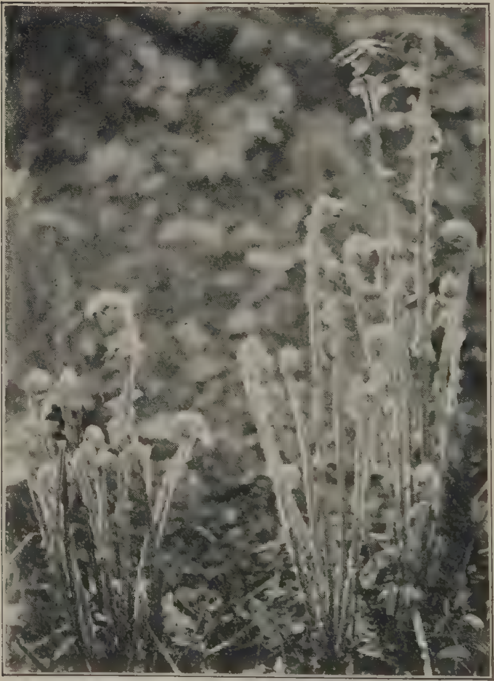


Fig. 138. Fern fronds unrolling from the buds. These so-called fiddle-heads occur profusely in our June woods.

In size most of our species of ferns are rather small plants, ranging from an inch or more in height in some of our botrychiums to five or six feet in the royal fern and the bracken. The main stem is a perennial one and usually grows underground, although primitive species, the tree ferns, possess a stout erect trunk sometimes fifty feet in height. (See Figure 137.) These tree ferns are still native in Australia and in a few other countries, while in the eastern part of our Dominion we find many of their fossil remains—an evidence of their previous existence here.

Ferns do not produce "flowers" as do other groups of plants. Together with the allied horsetails and club-mosses, known as the Fern Allies, and with many other forms, such as mosses, liverworts, etc., they are commonly designated the Flowerless Plants or Cryptogams.

Structure of a fern plant.—Most of our ferns apparently possess no true stem. It is only necessary, however, to dig up the underground part of almost any fern to find an underground creeping rootstock or rhizome. This is usually a horizontal, thickened stem, sometimes several feet in length. In a number of cases, such as the royal fern, cinnamon fern, and others, the stem is more or less erect and elevates itself a few inches above the ground. On this rootstock are found *true roots*. These grow mostly from the under side of the stem, are somewhat rigid, and are entirely fibrous and wiry in texture. At one end of the rootstock there is a growing point or *apex*, by means of which, during the growing season, it extends through the soil. From this end, also, are produced one or sometimes more buds, which are the beginnings of new leaves for the following season. These buds are of peculiar shape, being unlike those of most other plants. They are of a spiral pattern in all true ferns, being coiled downward from the apex in the form of a watch spring. This type of bud is known as *circinate*. When they burst from the ground in the early season, they are spoken of as "fiddleheads," from a fancied resemblance to the head of a violin. (See Figure 138.) Often these buds, and sometimes the whole rootstock, are protected by brownish chaff-like scales.

The most noticeable part of a fern plant is the leaf or leaves, the so-called *fronds*. These are of many varieties and are most striking in their grace and beauty of form.

Structure of a fern frond.—In the frond of the marginal shield fern shown in Figure 139, which is a type of many of our ferns, the broad expanded portion is known as

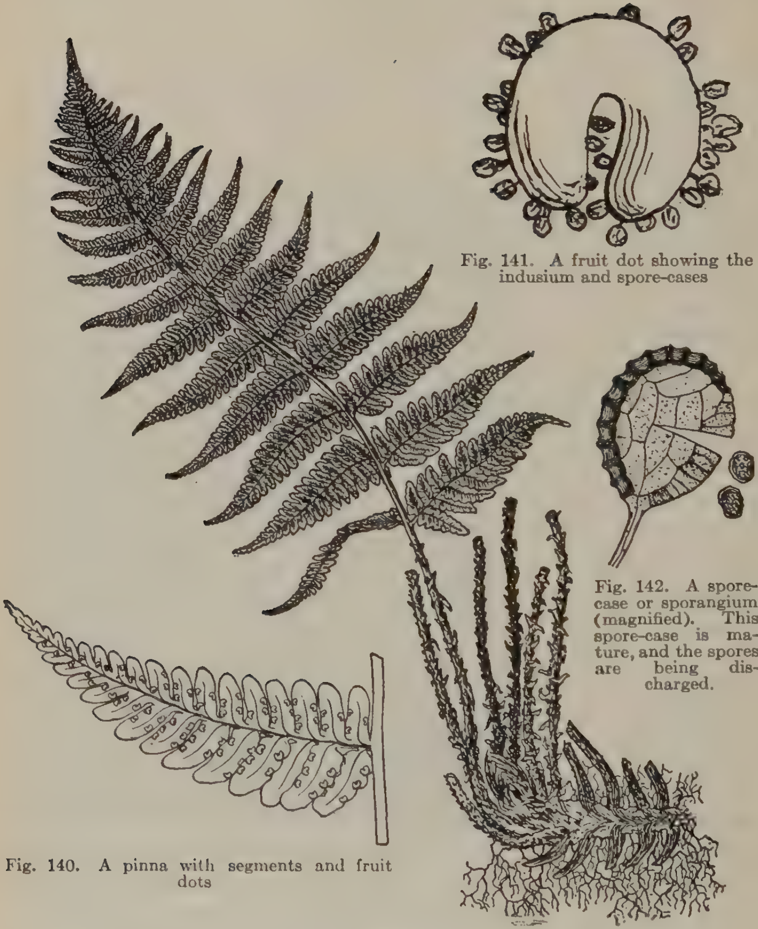


Fig. 141. A fruit dot showing the indusium and spore-cases

Fig. 142. A spore-case or sporangium (magnified). This spore-case is mature, and the spores are being discharged.

Fig. 140. A pinna with segments and fruit dots

Fig. 139. The marginal shield fern. The fronds are divided into pinnae and are produced from rootstocks.

the blade, and the stalk which attaches it to the underground stem is the stipe. The blade is dark blue-green on its upper surface and lighter beneath. It is thick in texture and in some cases evergreen. Running from the base to the tip of the blade is the midrib or *rachis*. This is but a continuation of the stipe. The lower part of the stipe is covered with a dense mass of brownish scales called the *chaff*.

The blade varies in structure, but in this instance it is made up of similar pieces arranged down the two sides of the rachis. These sections are called the *pinnae* (*pinna*, a feather). (See Figures 140 and 143.) They are sessile, or nearly so, and usually longest at about the middle of the frond. Toward the top they become smaller and shorter and gradually merge into each other. Thus they give the frond a feather-shaped appearance. Each pinna has a structure resembling that of the whole frond, that is, a midrib or secondary rachis, on each side of which are minute pieces known as *segments*. These are arranged on the pinnae very much as the pinnae themselves are arranged on the frond, and have somewhat rounded tips and broad bases.

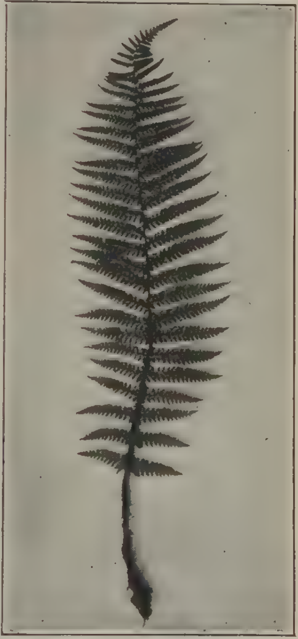


Fig. 143. A typical fern frond

If the surface of one of the lower pinnae is carefully examined with a lens, it will be seen that from its midrib a small vein branches off to form a small midrib in each segment. From this, in turn, still smaller branches pass off into either half of the segment. These branches are forked at the end, a method of veining known as *forked*, which is characteristic of many of our ferns.

Fig. 144. A fern colony. In this instance the requisite shade is furnished by tall forest trees.

An examination of the lower surface of a pinna taken from the upper half of the frond will reveal a number of small grayish or brownish spots about the size of pin heads. These are the *fruit dots* or *sori* (Fig. 140). They are found closely attached to the veins from which they grow and are characteristic structures of the majority of ferns. They are produced, in this case, on the under side of the frond and appear only after it has unfolded. Although not present on the ordinary fronds of some species of ferns and never found on very young fern fronds, these fruit dots afford one of the main distinctions between fronds and the leaves of ordinary plants. They are often quite numerous. On an average frond of a related species, the male fern, their number was determined to be 1807.

Structure of a sorus.—Each sorus on the shield fern frond measures about 1 millimetre ($\frac{1}{25}$ inch) in diameter. When young the sori are light lead-coloured, but later they are brownish and somewhat horseshoe-shaped. They are attached close to the margins of the pinnae and in some cases project over the edge. A closer examination shows a covering which is fastened at the inside but free around the outer edge. This covering is known as the *indusium* (Fig. 141). On the fronds of some species, such as the common polypody, the oak fern, and the beech fern, there are no indusia, and the fruit dots are therefore described as *naked*. Indusia may be circular, elongated, cup-shaped, star-shaped, horseshoe-shaped, etc. When the indusium is raised or removed, beneath and protected by it will be seen a number of minute bodies. These are called *spore-cases* or *sporangia* (Fig. 142). They average at least twenty to each fruit dot.

Structure of a fern sporangium.—If sporangia of the fern are examined through a microscope, each is seen to consist of a minute, hollow, oval-shaped, stalked body. Encircling it is an incomplete ring of cells known as the *annulus*. When mature and dry, this annulus breaks at the gap, and being somewhat elastic, suddenly straightens, thus shooting out the spores contained in the spore-case. If these spores alight in suitable soil, they soon begin to germinate.

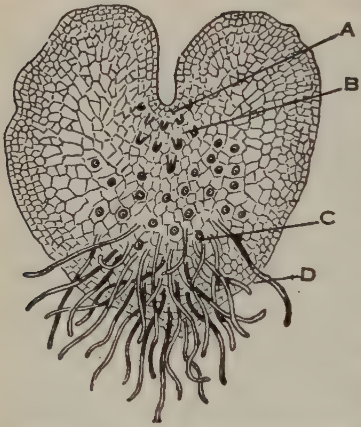


Fig. 145. A fern prothallium from below. A, the notch of the prothallium; B and C, reproductive organs; D, rhizoids

The spore and its development. — In each sporangium or spore-case the spores as a rule number sixteen. Each is a very minute, oval-shaped body, barely visible through the low power of the microscope. It is dark brown in colour and rough on the outside, and consists of a single living plant cell. The number of these produced by a single fern plant is usually very large. By a simple calculation, it was determined that a male fern plant possessing five fronds produced at least 5 x 1807 x 20 x 16 = 2,891,200 spores.

These spores do not resemble seeds and must not be mistaken for them. A seed can only germinate and grow into a plant similar to the parent plant. But when, under proper conditions of warmth and moisture, a spore of a fern germinates, it develops into a small ($\frac{1}{8}$ to $\frac{1}{4}$ inch), flat, green, heart-shaped body, known as a *prothallium* (Fig. 145). Where ferns are plentiful, these prothallia may often be found in humus around decaying moss-covered logs, or may be obtained from greenhouses, where they are often found under ferns in the soil. On the under

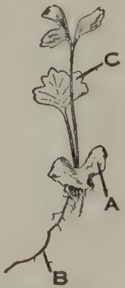


Fig. 146. A fern developing from a prothallium, A, the prothallium; B, the commencement of the rootstock; C, the developing frond

side of this minute plant body are developed two different kinds of outgrowths, from which, by their union or fusion, there originates a young fern plant, which in time becomes a mature plant capable of producing spores like those described. (See Figure 146.) Thus the life history of the fern is completed.

Besides this method of reproduction and development, many kinds of ferns are able to reproduce their species vegetatively; some by special buds, as in the bulblet fern; some by severing of rootstocks, as in the bracken; others by sending out underground stems, which form new plants at their tips, as in the ostrich fern; and still others by striking root at the tip of the fronds, as in the walking fern.

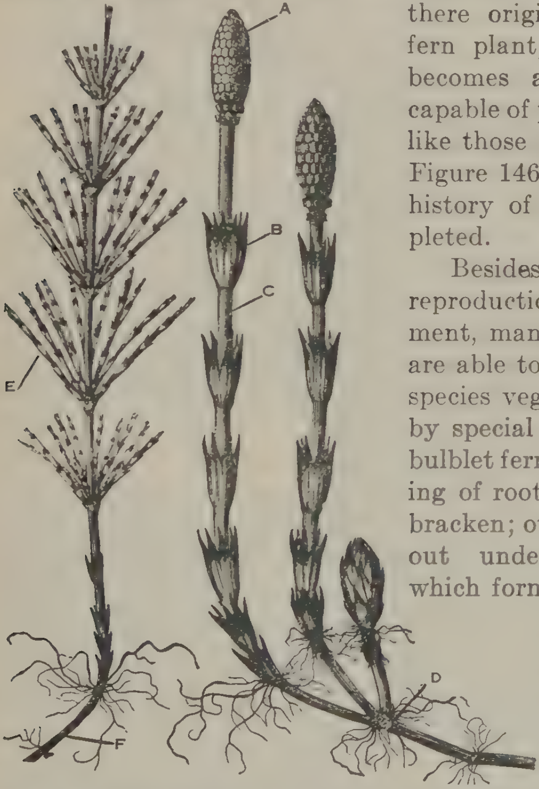


Fig. 147. A sterile and a fertile stem of the common field horsetail. A, the fruiting cone; B, the toothed sheath; C, the internode of the stem; D, roots; E, a branch; F, the rootstock

THE FERN ALLIES

Two families of plants, the horsetails and the club-mosses, resemble the ferns in many respects, but differ from them greatly in appearance. The horsetails are common throughout Ontario, but the club-mosses are quite rare except in the northern limits of the province. It is this last family which furnishes so much of our well-known "Christmas green," from which our festive decorations and Christmas wreaths are made.

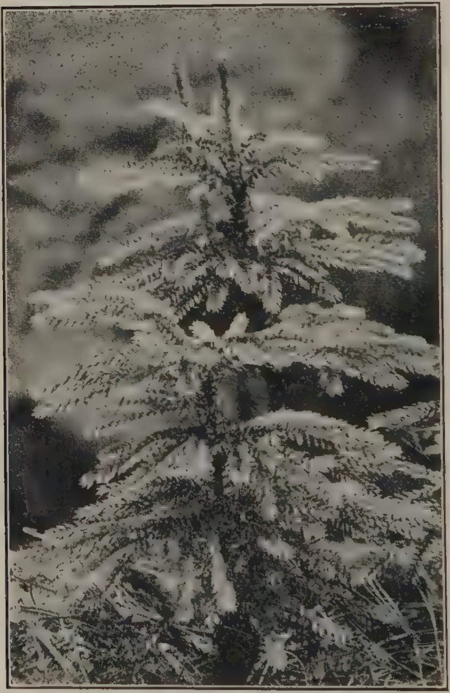


Fig. 148. The ground pine. This club-moss is a favourite for Christmas decorations.

The horsetails. — One species of this family, the common field horsetail (Fig. 147), in one of its stages is found growing in the spring almost as soon as the frost has left the ground. It is particularly fond of sandy banks and soil along railway tracks. It appears in groups or colonies. The stem is brownish, ridged, jointed, and about eight inches high. It is without branches and terminates in a cone-shaped body from which the spores are produced. This is the fertile stage of the horsetail. It develops from a rootstock as do the ferns.

Later in the season, from the same rootstock grow other totally different stems. These are from eight to ten inches in height, green, jointed, and with whorls of jointed branches. Such stems are sterile and do not produce spores.

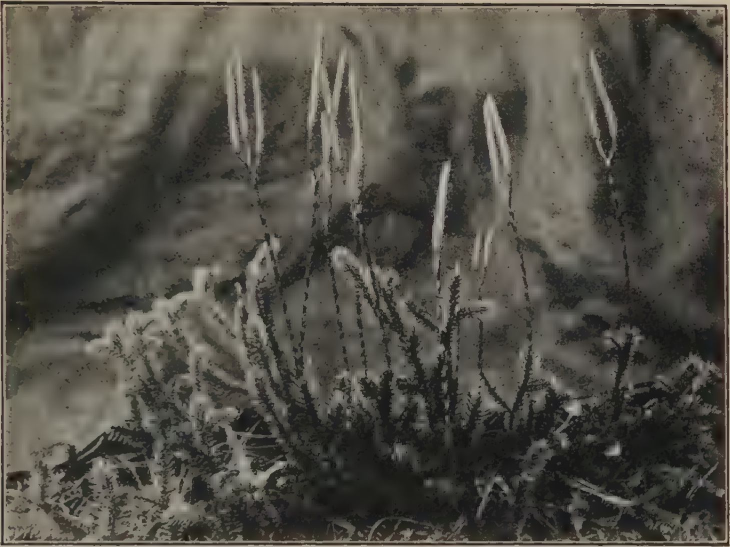


Fig. 149. A club-moss in fruit. The spores are being produced from the cones on the plant.

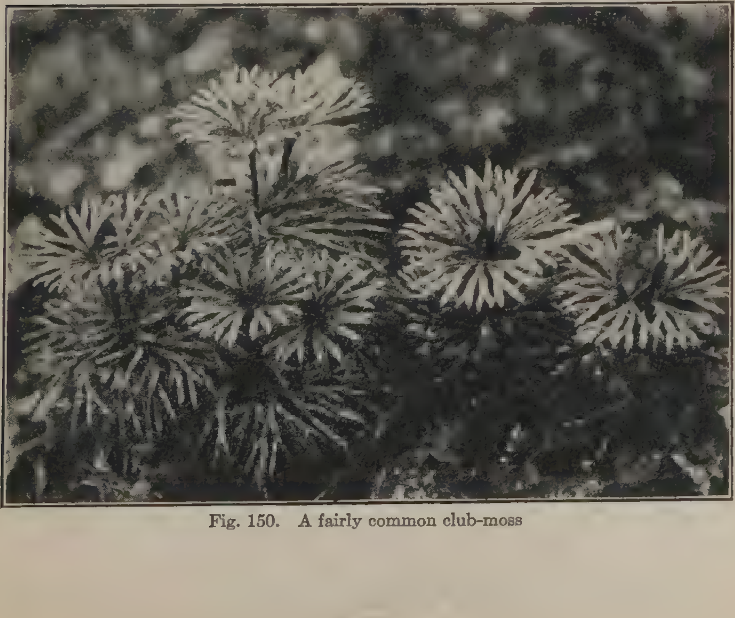


Fig. 150. A fairly common club-moss

The club-mosses.—The ground pine (*Lycopodium obscurum*) is probably the most common form of this family in Ontario. (See Figure 148.) It, too, grows from a rootstock. These bear erect stems about six or eight inches in height. As these stems are branched and covered with minute, shining, evergreen leaves, they have much the appearance of young hemlocks. At their tops grow from one to four pale green spikes; these are the spore-producing part of the plant.

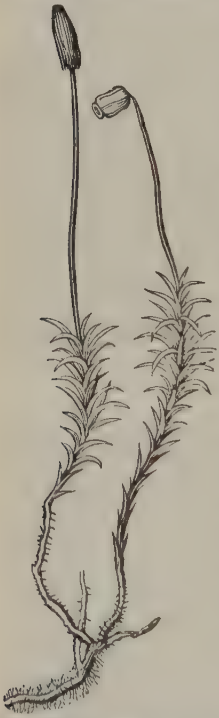


Fig. 151. A common moss plant. Compare this with the club-moss.

It is an interesting fact that the club-mosses were among the most important coal-producing plants. They were not, however, of the slender, trailing type that we are familiar with in our cool northern woods, but towering trees that would not be dwarfed in comparison with even the tallest of our oaks and elms. Petrified specimens of these trees are often found in the coal mines. They are so large and heavy that it is sometimes necessary to support them, in order that their accidental falling may not endanger the lives of the miners.

THE MOSSES

This group includes a great many small plants, from one-half to three or four inches in height, that are apt to be confused with the club-mosses. They often form green mats, covering damp, decaying logs or tree trunks. Like the club-mosses the mosses are green in colour, but they differ from these plants in not growing from rootstocks. (See Figure 151.)

CHAPTER XVI

THE RELATIONS OF PLANTS TO THE WORLD ABOUT THEM

The web of life.—In nature nothing stands alone; each factor is associated directly or indirectly with the others. This more or less intimate relation of all the components may be compared to a vast fabric made up of many threads woven together.

These various relations form a system so nicely adjusted that it is frequently spoken of as the "balance in nature." An example of this can be seen in an aquarium where the plants and animals bear the proper numerical relation to one another. Both the plants and the animals absorb oxygen and give off carbonic acid gas. All the oxygen, however, is not exhausted, as the green plants in sunlight absorb carbonic acid gas and liberate oxygen. It is evident, then, that if the plants are present in sufficient numbers, they will supply enough oxygen for themselves and the animals. An aquarium in which such conditions prevail is said to be properly balanced.

The study of the relationship of plants and animals to each other and to seasons and environments is known as *Ecology*. Such relations may be with other plants, with animals, or with inanimate nature.

Relations of plants to each other.—Some plants are helpful to their neighbours. Certain trees and shrubs, for instance, support climbing plants; others provide shelter from the sun for ferns and other shade-loving species. But when plants are crowded, they rob each other of such essentials as moisture and light.

Relations of plants to animals.—The lives of plants and animals are closely associated in many ways. To the botanist perhaps the most important of these relations is that which exists between plants and insects. Some plants and insects are constantly at war with one another, and, as a general rule, in this struggle the insects are victorious. Especially is this true among our cultivated plants, which have to be protected by spraying and other devices to prevent them from succumbing to insect attacks. It must not be supposed, however, that plants carry on an entirely defensive war against insects. In Chapter VIII examples have been given of various insects which are attacked successfully by fungi.

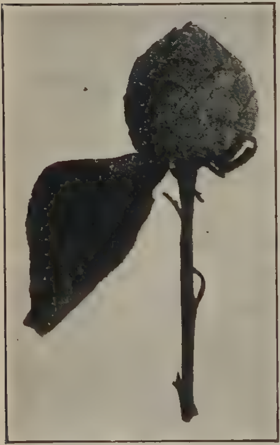


Fig. 152. A common gall on willow. This gall is produced by an insect somewhat resembling a mosquito.

The relations between certain plants and insects are always of this warlike character. Some insects can never live on terms of peace with plants, and some species of plants wage an incessant war against insects. But many plants and insects live upon friendly terms, and some even go so far as to establish relations of mutual helpfulness. In Chapter VI we learned how insects gather nectar and pollen from flowers, and how they return this kindness by cross-pollinating the flowers. The benefit is mutual: the insects are supplied with food materials, while the plants, because of the insects, are enabled to produce seeds of better quality and in greater quantity than they otherwise could.

Most mysterious of all the relations existing between plants and insects is that which is involved in the formation of the deformities on plants, commonly known as *galls.* (See Figures 152 and 153.) The insects which produce the galls are always deadly enemies of the plants concerned; nevertheless the plants construct for them beautifully designed defensive shelters, provisioned with food supplies sufficient for all the stages of the occupants' development. This act of "kindness" on the part of the plants is surely surprising in a world where existing plants and animals are the survivors of a life-and-death struggle. A possible explanation may be that the plants have produced the galls as places of internment for their enemies, thus restricting their injurious operations to a limited area.

The insect galls on the oaks—the "oak apples" (Fig. 154)—are common throughout Ontario. Since the black oak retains the majority of its leaves during the winter, the "oak apples" originating from them also remain attached, and at that season trees laden with those objects often form a conspicuous feature of the landscape. The galls in winter are brown in colour, and so dry that a very light pressure serves to break the fragile shell and disclose the abandoned home of its insect producer. The course followed by it in emerging can still be traced. It has passed through the hard, dense layer that formed an innermost line of defence, traversed the comparatively thick, spongy layer, and reached the outside by cutting a neat, round hole in the gall rind.

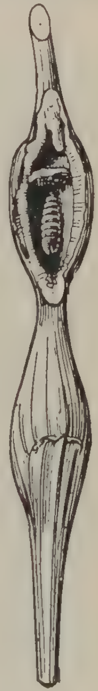


Fig. 153. A gall on the stem of golden-rod. This gall is produced by a species of moth. The upper gall is cut open.

Earlier in the season, the centre of each gall was occupied by a plump, white, legless larva, which fed on the contents of the cells surrounding it. Gradually this larva has changed into the wasp-like insect which has bored its way to the outside.

Relation of plants to inanimate nature.—In the realm of inanimate nature, plants bear relations chiefly to temperature, soil, light, and moisture.

Temperature.—Ontario furnishes several good examples of the relation of climate to tree distribution. The striped maple and the jack pine are northern species, while the cucumber tree, the black gum, and the chestnut are confined to the Lake Erie region in the south.

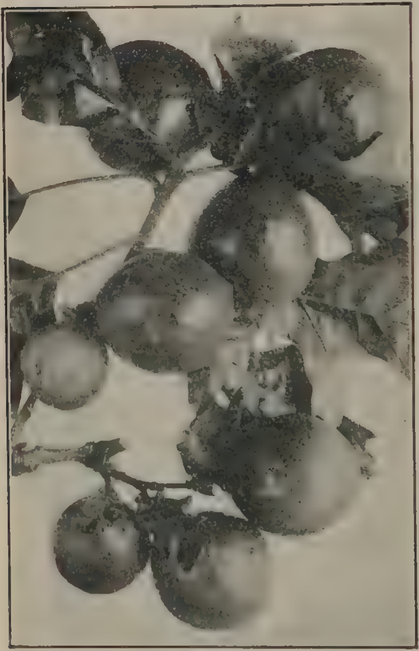


Fig. 154. Oak apples. The producers of this species of insect gall emerge from it in the fall.

Soil.—The nature of the soil has a distinct relation to plant growth. To make it suitable for his crops, the farmer modifies the properties of the soil by tillage, or corrects its chemical composition by the application of the necessary fertilizers.

Light.—Although all green plants require light, only comparatively few of them thrive well without some shade. In Chapter X we discussed various devices by which plants secure the best supply of light. Since most of our native plants are shade loving, they are becoming less abundant as the clearing of the land exposes them to the full glare of the sun.

Unfortunately, with the passing of the snake fence one of the last places of refuge of our wild flowers is being destroyed. The zigzag line of the fence forms cool corners in which shade loving plants find a sanctuary. There for several decades they can survive the cutting down of the trees that formerly shaded them. If such fences are built soon after the land is cleared, the plants do not suffer by the removal of the natural shade.

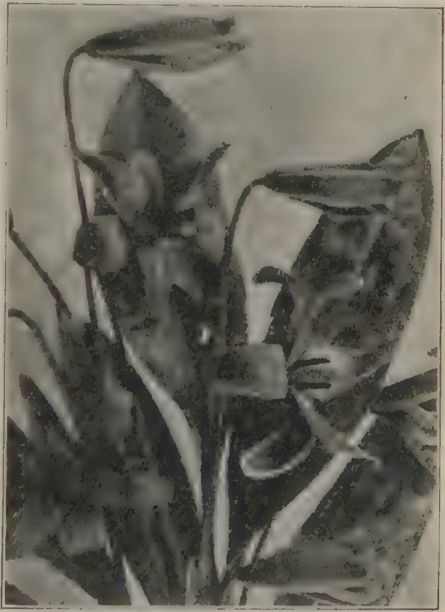
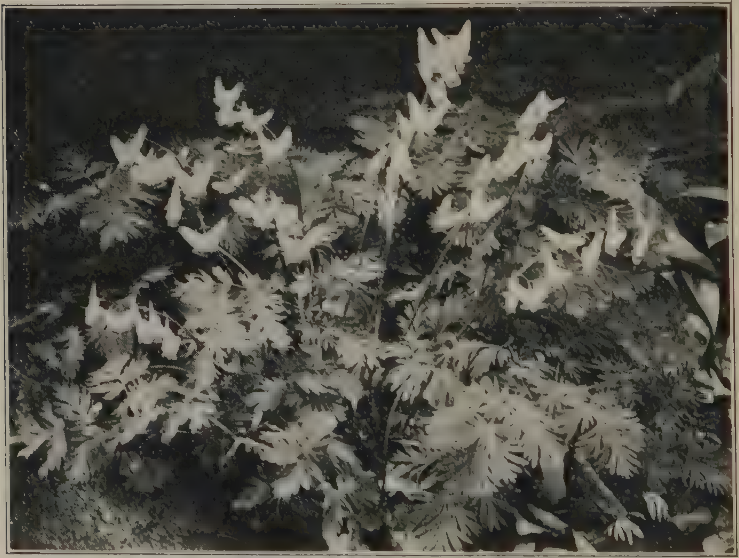


Fig. 155. Adder's tongue lily

The majority of our earliest spring flowers may be found in the shady nooks of these old fences. There, the spring beauty and the hepatica rival each other in a contest to produce the earliest bloom. There, the purplish-spotted leaves of the adder's tongue lily (Fig. 155) are seen often in almost woodland profusion. The nodding yellow flower bells are not quite so plentiful as in the woods, but nevertheless are not uncommon. In some of the fence corners the May apple, a victor in the "struggle for existence," has overrun the whole territory. Other flowers are there of such a delicate structure that the sight of them along the fence rows brings a thrill of delight. The blood-root, wrapped in its leafy cloak, clings to the friendly shelter of the fence, although the woods with their kindly shade have receded far. And here and there are clumps of Dutchman's breeches, their pearly-white, yellow-tipped flowers presenting a pleasing contrast to the light green shades of their soft, much divided foliage. (See Figure 156.)



— *Courtesy of A. B. Klugh, Kingston*

Fig. 156. Dutchman's breeches

Flowers sensitive to the sun thrive in the shady retreats along the snake fences. Very little sunshine filters through between the fence rails, and trees and shrubs spring up and help to increase the shade. In the past, protected by the fence, the sapling growth left by the logger soon spread out to the typical wide-branched trees of the open spaces, and the winged seeds of the elms, the maples, the basswoods, and other trees of the neighbouring woods germinated and in a few years established natural nurseries in the fence corners. To the flower lover, the discarding of this old-fashioned fence is a cause of genuine regret.

Moisture.—One of the chief essentials to the growth of plants is moisture, which they derive from both the soil and the air. Plants, like animals, vary in the quantity of water which they require.

Many, because of their special structural adaptations, are capable of growing wholly in water, and could not exist under other conditions. Others which thrive where there is very little moisture in either soil or air, if subjected to very moist environments for any length of time, would soon perish. Each species has its own particular requirements and seeks out the conditions which will satisfy these. Our common dandelion, for example, occurs very plentifully in its growing season on dry lawns and in open fields, where, though the moisture is limited, it flourishes. This

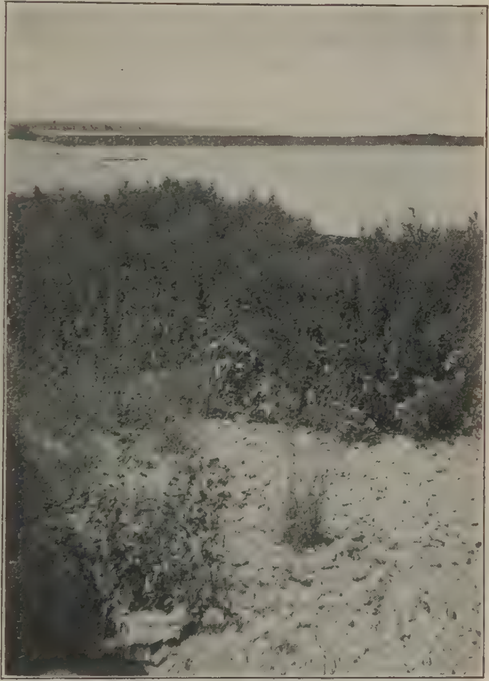


Fig. 157. A colony of yellow dock. A small runlet of water was the cause of these plants establishing themselves on a pebbly beach.

is due to the fact that it has a long, stout tap root which is especially adapted to draw and retain the moisture from the deeper layers of soil, and also that the drying out of the root is checked by the thick cluster of leaves which closely covers the soil above the root. This may be observed by pulling up one of these plants with its root, when it will be found that the soil underneath the leaves is usually more moist than that which is not so covered. The polanisia, too, which grows in warm, dry sand, is able to procure sufficient moisture for itself by sending out its extremely long fibrous roots on all sides to a distance of several feet. Moreover, the surface of this plant is hairy and sticky, and therefore moisture does not evaporate readily from its stem and leaves. On the other hand, plants such as water-lilies, cat-tails, etc., adapted to grow in very moist situations, would soon perish if subjected to conditions of minimum

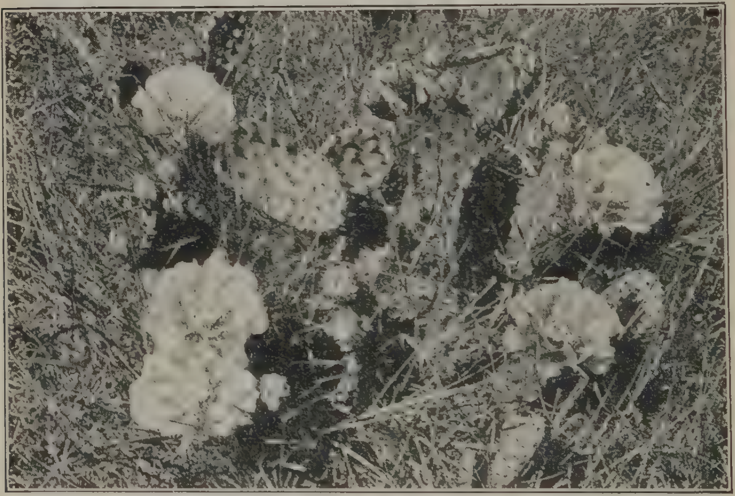


Fig. 158. Prickly pear cactus. These plants are of the true desert type. In Ontario they are found only at Point Pelee.

moisture. This principle is recognized by horticulturalists in the planting of garden plants. As every experienced gardener knows, the Alpine group of plants should be set in open, dry, sunny situations, while other groups, such as the ferns, must be placed in moist, shady spots.

Some plants are perfectly adapted to live in sandy, desert regions, where there is little rainfall. One interesting plant that thrives under such adverse conditions is the cactus, of which there are many species. Only one of these, however, is found in Ontario. (See Figure 158.)

Like all desert inhabitants the cactus must guard its water supply very carefully. This is stored in the fleshy stems, and very little is lost by transpiration. The leaves of the common plants carry out this function of storing water, but in the cactus both leaves and branches are, as a rule, represented only by spines.

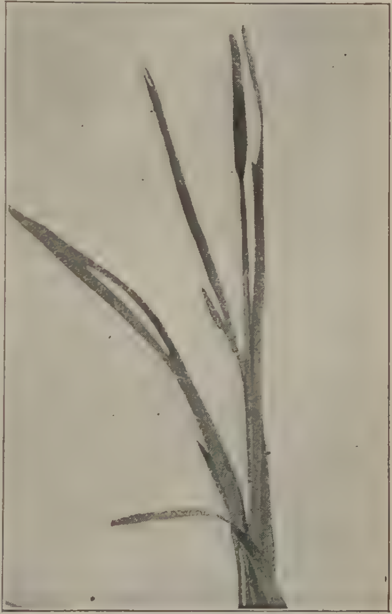


Fig. 159. Cat-tail flag. Plants of this species belong to the water-loving group.

Such care is taken by the cactus against loss of water that much of it is accumulated in the stems of the plants. The desert travellers are well aware of this and often replenish their water supplies from the cactuses. The so-called barrel cactus is the one usually selected as a water reservoir. As this plant grows to a height of only about five feet, the top can be readily cut off. If this is done, the interior of the stem is found to be filled with a watery mass. This is pounded, and the liquid is squeezed out of the resulting pulp. The water thus obtained is said to be very good.

Of the water-loving plants, we possess many species: (1) Those plants which grow entirely in water, such as the small, floating duckweeds (*Lemna*); (2) plants with leaves wholly or partially floating while their roots are embedded in the soil or mud at the bottom; such well-known plants as water-lilies, water buttercups, and pond-lilies, belong to this group; (3) plants which do not float, but which grow in a more or less erect position in water, such as cat-tails, marsh marigolds, pickerel-weeds, water plantains, water docks, and many others. Such plants as these, being wholly or partially surrounded by water practically all the time, never lack sufficient moisture.

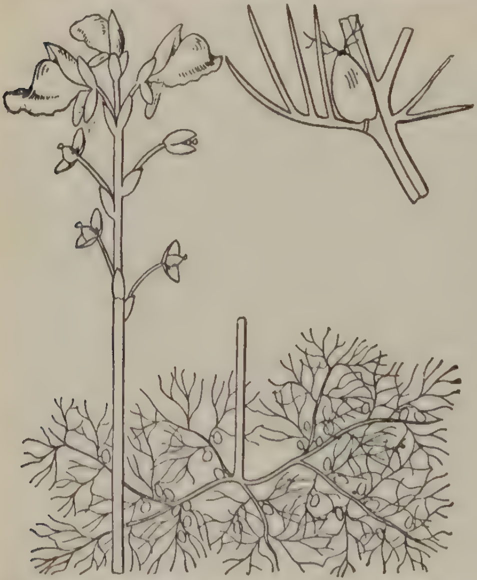


Fig. 160. A common bladderwort. In the upper right-hand corner is shown one of the traps enlarged.

A very interesting type of water plant is the bladderwort (Fig. 160). As this plant is not held by roots and has fine flexible stems, it floats freely suspended in the water. Along the stems are many leaves broken up into small, thread-like divisions. Among these are the small bladders to which the plant owes its name. Each of these little sacs contains a bubble of air, so that they collectively serve to float the plant. Their chief use, however, is to keep the plant supplied with an animal diet. The opening in each sac is closed by a valve. This yields easily to pressure from without, but resists the efforts of the small prisoners trying to escape by forcing it open from within. The traps are so effective that they invariably contain small larvae of gnats, tiny worms, and other members of the aquatic life of the locality.

It is difficult to surmise why the unfortunate little creatures enter the cunningly devised prison. Is it by chance? Or do they push through the fatal doorways in search of food or in an attempt to elude an enemy?

Some of the animals captured live longer than others, but the final result is the same; they all die, and the products of their decaying bodies serve to provide nitrogen compounds to the plant. This supply of food would seem to be important to the plant, as its submerged, finely dissected leaves do not expose much surface to the light, and, consequently, the amount of food manufactured must be small.

Zones of vegetation.—The adaptation of plants to different soil and moisture conditions is often very marked about many ponds and lakes and along the margins of slow streams. In such places, water plants of like habits are often found along the shore in definite stretches or zones, according to the depth of the water. Such an arrangement of plant associations is known as zonal distribution of plants or *zonation*. Almost any one of our small lakes with a low shore-line will furnish examples of zonation. Figure 161 illustrates such zones. Examine it and pick out as many zones as you can, commencing at the water.

Community grouping.—Moisture, however, is not the only condition which determines the grouping of plants. Plants of different species are frequently grouped into communities. The plants which form these communities vary in different regions according to prevailing conditions of climate, soil, sunlight, etc. The group known as "Plants of the Hardwood Forests," for example, includes such varieties as the following: Maples, oaks, elms, ironwoods, basswoods, trilliums, hepaticas, phloxes, wintergreens, Canada violets, dog's-tooth violets, squirrel corn, Dutchman's breeches, blue cohosh, and Solomon's seal.

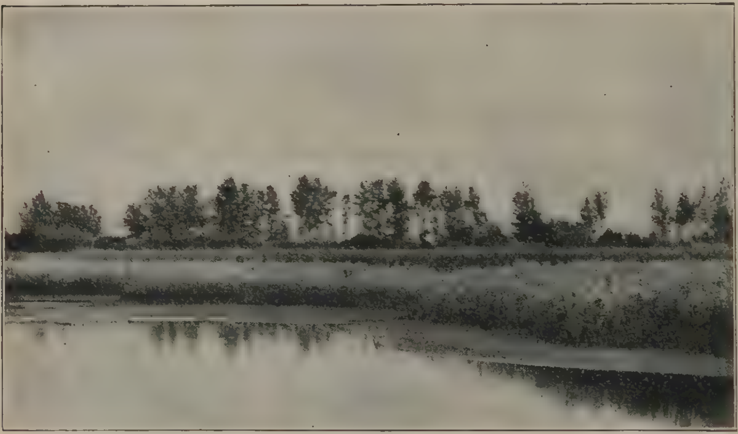


Fig. 161. Zones of vegetation

Other similar groups are:

Plants of the roadside
Weeds of the garden
Swamp plants
Lawn plants
Rock plants
Sand plants.

It is suggested that the student should make for himself a list of each of these for his own locality.

PRACTICAL QUESTIONS AND SUGGESTIONS FOR OUTDOOR WORK

1. In the following plants state the nature of the injury often caused by insects: Apple, potato, cabbage, corn, rose, golden glow, and nasturtium.

2. Why are willows, in preference to other trees, often planted along the banks of streams?

CHAPTER XVII

FORESTATION

The value of Canadian forests.—The economic future and national prosperity of Canadians is dependent on the continuous utilization of natural resources. The forests are among our greatest natural resources and are not the property of any single generation. The immense wood-using industries that have reached so successful a development in Canada should remain productive and continue to be a source of revenue to future generations.

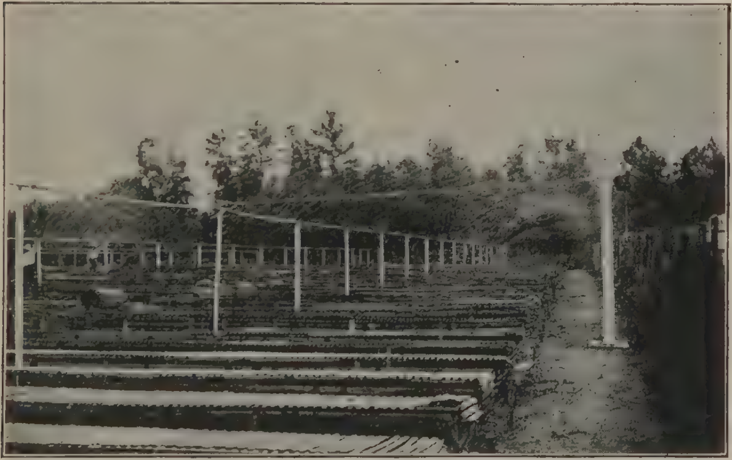
The total area capable of growing merchantable forests in Canada is estimated at approximately 1,200,000 square miles. Because of the extremes of climate and the character of the soil, much of the land included in the Dominion is not available for successful agricultural development. Approximately one-half of this untillable area is forest land.

In the valuation of forests, it must be understood that, directly and indirectly, their contribution to the national income ranks only after agriculture and manufactures. The annual production of wood for all purposes approximates three billion cubic feet, with a value of almost a quarter of a billion dollars. This means that for each of her citizens Canada produces annually over three and a quarter cords of wood valued at eight dollars a cord.

Forests and forestry.—Trees and timber stands are not, like minerals, inanimate objects, but are complex living organisms which grow, mature, and die. A mine may become exhausted through exploitation. A forest wisely administered never becomes depleted; as trees are cut, others grow to take their places.

Mature timber does not increase in volume, but remains stationary or even decreases. New growth only balances losses from natural causes. Merchantable timber, therefore, should not be hoarded, but on reaching maturity should be cut, so that another generation may become established.

In forestry, as in agriculture, one crop is succeeded by another. Usually, indeed, preparations are made for the next generation before the final harvesting of the first.



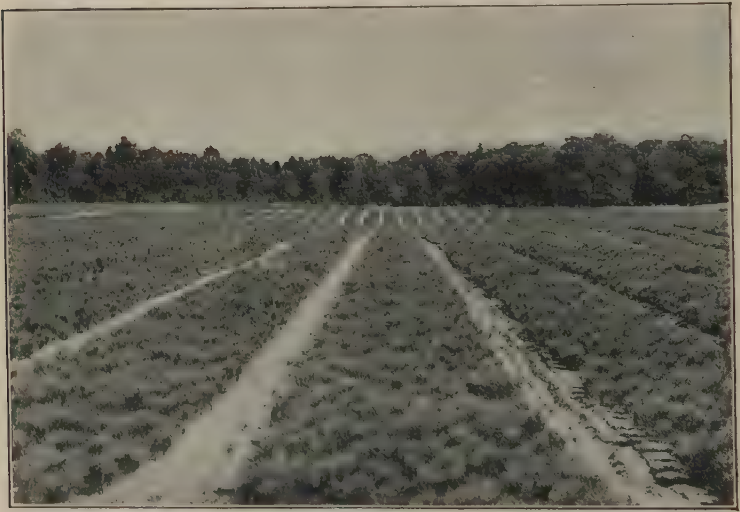
—Courtesy of Ontario Department of Lands and Forests

Fig. 162. Seed beds, showing an overhead watering system and shades made of lath

When mistakes are made in field crops, only one season is lost. In the forest many years must pass from the seeding to maturity. When enemies enter and destroy young stands of trees, many years of productivity are lost, and the task of again establishing new growth becomes more difficult.

Regeneration methods.—The methods by which young woods are made to succeed the parent stand fall into two main groups: (1) Regeneration by natural means, (2) reproduction by artificial methods.

Natural reproduction.—When forests are regenerated by natural means, the merchantable timber is cut in such a way that ground areas, plentifully seeded, are left throughout the forest. There are several different systems by which this is achieved. The method to be adopted is determined by the location and the peculiarities of the species to be regenerated. The problem is made more difficult by the irregularities of the seed crops. In all of the cutting methods the general principle is the same. The forest is opened up more or less widely by logging, thus allowing the sunlight to penetrate to the forest floor. The remaining trees seed up the ground, which, due to the action of the sunlight, has become more receptive. After the young trees are successfully established over the whole area, the remaining timber is removed at the discretion of the forest owner.

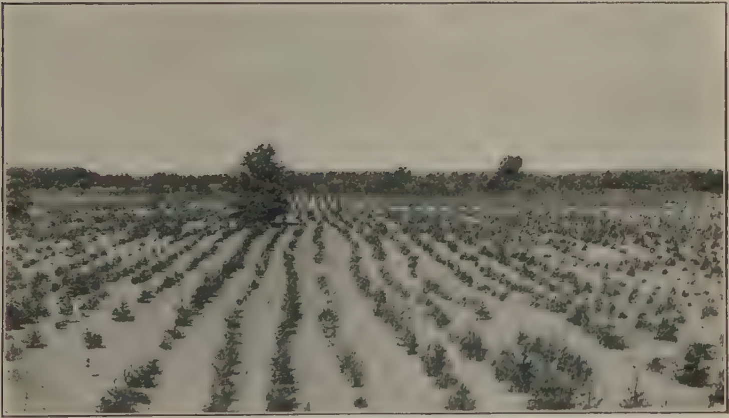


—*Courtesy of Ontario Department of Lands and Forests*

Fig. 163. Red pine transplants ready for final planting

In certain of the broad-leaved species, the forest is renewed by coppice growth. The parent stand is completely felled. Reproduction commences immediately from the stumps and roots of the old trees and from seedlings on the ground at the time of cutting. In Europe, coppice forests supply low-grade hardwood on short rotations of twenty to thirty years. Any application of this method in North America will be to furnish a rather special product of no great importance.

Artificial reproduction.—Where young woods are made to grow by sowing seed or planting trees, the method is artificial. Artificial measures of forestation are more methodical and systematic than natural means, where conditions depend largely on a whimsical mother nature.



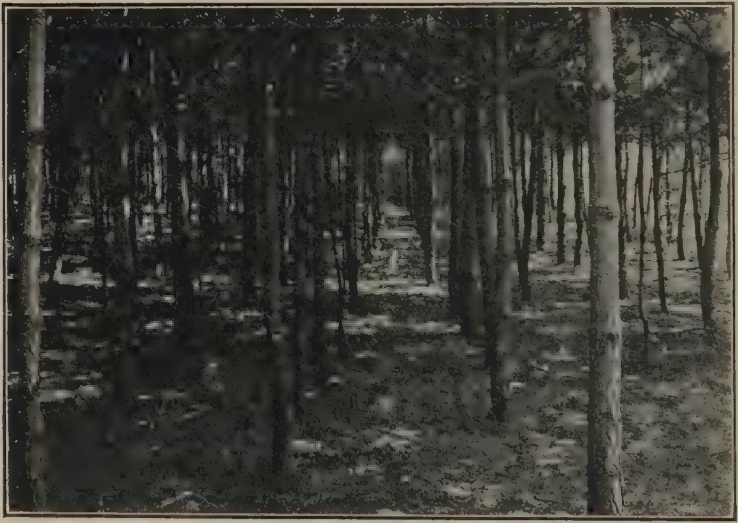
—*Courtesy of Ontario Department of Lands and Forests*

Fig. 164. A three-year-old jack pine plantation on sand plains

In Canada, establishing young woods by seeding is still in the experimental stage. As the initial expenditure is relatively low, some of the great denuded wastes may be converted into valuable timber lands by this method.

Where young woods are started by planting, the trees are conveyed to the final site from the forest nursery where they are grown. Usually the planting is in rows of definite spacing, although frequently irregularities of topography interfere with such practice. These young forests so established are called plantations.

In the nursery the trees are cultivated under rather special conditions. Seed is sown in beds, where the seedlings remain for from one to three years. During the first few weeks after germination, it is necessary to provide special protection for the beds against climatic extremes and such enemies as insect and fungous pests. The seed-bed period may or may not be followed by transplanting. With conifers, especially, transplanting is usually practised. In this process the seedlings are lifted from the beds, where lack of room has handicapped their full development, and are planted in rows where sufficient spacing for individual



—Courtesy of Ontario Department of Lands and Forests

Fig. 165. A thirteen-year-old jack pine and Scotch pine plantation on sand plains

growth is provided. In general, then, in Canada, nursery stock intended for reforestation purposes is from two to five years old.

Young stands.—After young forests have become established, whether by artificial or natural measures, the life story is but begun. From youth to old age the trees develop steadily but in more or less definite periods.

At first the young trees expand laterally, to produce crown surface for food manufacture, but soon neighbour touches neighbour, and growth is upward. During this period the trees grow rapidly in height, while at the same time the lower branches are gradually shaded out or are cut out. Under management, young thickets are often thinned and freed so that competition is not too severe. In thinning, however, the individual crowns must be sufficiently restricted so that the lower branches die; otherwise knots are formed, and the final product is of low grade.

After the youthful period of very rapid growth in height, the tree reaches the stage when it increases most in stem diameter. Each year's continuous layer of wood is laid down all over the tree, while the struggle for existence continues apace. In this stage, also, thinning improves the development of the stand.

The length of the period during which the tree produces wood depends upon the length of the life of the species. Again, the cutting out of the poorer trees improves the quantity and quality of the final product.

Finally, from middle age the stand passes into maturity. The growth in height becomes less, and there is little increase in wood production. The forest is now mature and ready for the mills, where it is manufactured into lumber, newsprint, and other commercial products.

Enemies.—Our Canadian forest wealth is constantly suffering loss from enemies. While the careless operator's indifference and disregard for the future are serious, our primary problem is fire. In order to maintain a continuous annual yield the forests must be protected from fire. Each year forest fires cause tremendous losses through the destruction of quantities of merchantable timber, and convert vast productive areas into barren wastes which can seldom be reclaimed. Forests also suffer considerable loss from various fungous diseases and forest insects, which take their annual toll.

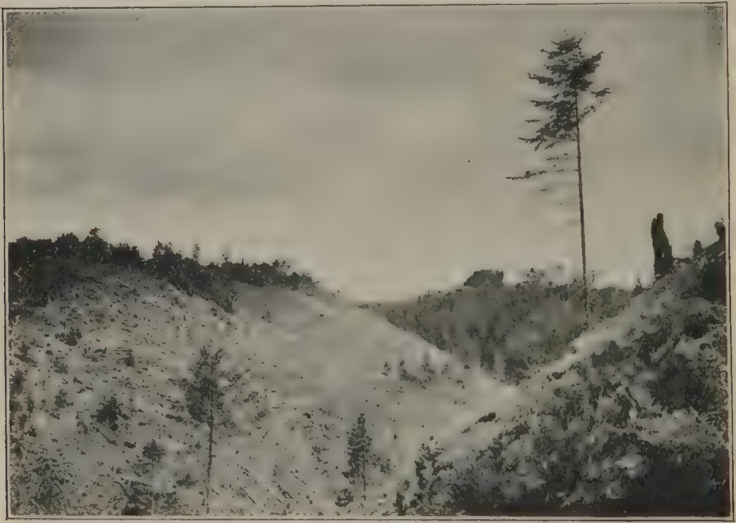


Fig. 166. A fire-swept area

Against these formidable enemies that menace our forests even the wisest administration cannot ensure perfect protection. Disastrous fires may lay waste wide areas; serious outbreaks of insects and other pests may make it necessary to cut large stands of infected trees. In these circumstances it is very important that measures should be taken to reforest the denuded areas. Since ninety per cent of Canadian timber land is controlled by the Crown, every

Canadian has a share in these forests and an interest in their future productiveness.

Besides ensuring a valuable crop of timber, however, other beneficial results follow the reforestation of regions unsuitable for agriculture. The roots of the trees hold the soil and prevent it from being either washed away by heavy rains or carried off by the wind. A wooded area also retains the water and acts as a reservoir from which the streams receive a constant, regulated supply. Streams that are thus fed do not flood in the spring and fall and dry up in the summer, but remain at approximately the same height throughout the year.

Planting a tree.—The first step in the process of planting is to prepare the tree. Any roots that have been injured in digging up the tree should be carefully trimmed off, and any long straggling roots shortened. The reduction of the root system will necessitate pruning out the branches that seem superfluous and cutting back the others. If the tree is not more than four years old, it is necessary to remove only the last year's growth, but with older trees the growth of at least two seasons should be cut off. It is not advisable to prune the tops of evergreens, and, if the tree has a single leader, the reduction of the top should be made entirely from the side branches.

If a number of trees are to be set out, the whole area to be planted should be cultivated. If this is not done, the holes should be made much larger than is necessary to include the root system when spread out. Before setting the trees, partly fill the hole with soil and well rotted manure. Plant the tree at about the same depth as it has been growing before. Take care to sift fine soil in about the roots, tramping it down to ensure its close contact with them. After the hole is filled, sprinkle a little soil loosely about the tree to act as a mulch and prevent too rapid evaporation.

Water the tree well after planting, and see that it is kept sufficiently moist for several days.

Cuttings.—Poplars and willows can be grown more readily from cuttings than from seed. In the case of willows, even branches broken from the trees by the wind will root if the conditions are favourable.

Both of these species may be grown from the so-called simple cutting. This is merely a part of a branch, from six to twelve inches in length, on which are two or three buds. The cutting should be straight and as uniform in size as possible. The best results are obtained if the cut is made just below a bud, as the roots start most readily from the joints.

Cuttings of trees are usually taken in the fall, packed in sand, and stored in a cool place for the winter. By the spring the lower ends that have been in the sand are calloused, and the cuttings are ready for planting. They are set in the soil so that one or two buds are above the surface.

Cuttings from geranium plants strike root very easily. For winter bloom they should be made in August from vigorous garden plants. The best results are obtained if the cuttings are started in damp sand. As a rule, some of the leaves are removed from the cutting to prevent too rapid evaporation before the roots are developed.

Grafting.—The process known as grafting is the insertion of a part of one plant into another in such a manner that the cambium tissues of the two plants can unite. The piece of the plant inserted is called the *scion;* the plant into which it is inserted, the *stock*.

Grafting serves a number of purposes. It is used to perpetuate varieties that do not come true from seed; the McIntosh Red apple, which was at first known only as a single seedling, has been spread by grafting over a large area in eastern Ontario. Grafting is employed also when it is considered advisable to dwarf a species, as when a pear is grafted on to a quince. It may be used to adapt a plant to new soil conditions; the plum, for example, is not adapted to sandy soil but thrives much better when grafted on to a peach. Another very important use of grafting is to perpetuate so-called "bud sports." These are individual branches which show valuable qualities. They cannot be preserved in any way other than by grafting. Many of our best varieties of apples, pears, and oranges were obtained in this way.

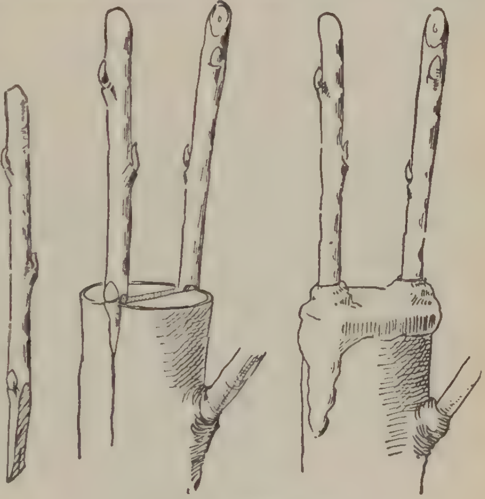


Fig. 167. Cleft grafting

Cleft grafting.—There are several methods of grafting, which differ chiefly in the mode of union of the scion and the stock. The following is the description of cleft grafting (Fig. 167), which will serve as a type of all the methods. A branch of the stock not more than two inches in diameter is sawn off. The stub is split down the centre and held open by the wedge on the blade of the grafting knife. This is removed after the scions are inserted, as the pressure holds them in place. At the lower end the scion is shaped like a wedge, with one edge thicker than the other. The sloping part is cut so as to leave one bud at the upper part of the wedge and on the thicker side. There should be on the scion at least two buds above this one. In adjusting the scion its cambium on the thicker side is placed in contact with the cambium of the stock. All cut surfaces are then covered with grafting wax made by melting together resin, beeswax, and tallow. The wax usually covers the lowest bud of the scion. The scions are cut when the trees are in the dormant state and are kept under the same conditions as cuttings. Grafting is done in the early spring, just before growth begins.

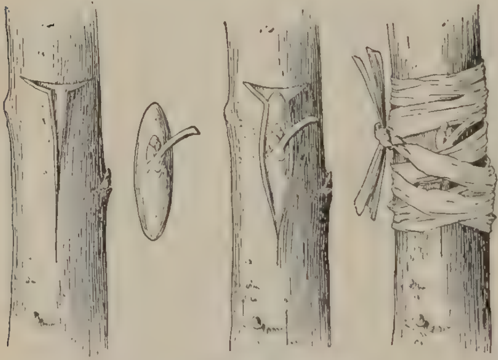


Fig. 168. Budding of a fruit tree

Bridge grafting.—If a tree is girdled, but the strip of bark removed is not more than four inches wide, the edges of the bark are trimmed, and the whole wound surface is covered with grafting wax and bandaged with cloth. If the wound, however, is wider than four inches, it is necessary to "bridge" it. To do this, trim back the edges of the bark and insert several scions across the wound. These should be freshly cut and should have all their leaves removed. Both ends of the scions should be cut wedge-shaped so as to extend under the bark about an inch above and below the wound. After the scions are in place, cover them and the barked surface with grafting wax and a bandage of cloth. If the scions grow, they will serve as channels by which the food manufactured in the leaves can reach the parts of the tree below the wound.

Budding.—This operation is merely a form of grafting, in which the scion is a single bud. The bud is sliced off the selected twig on a shield-shaped piece of bark about an inch in length. (See Figure 168.) The bark is usually cut straight across at the upper end. In preparation for the insertion of the bud, a T-shaped cut is made through the bark of the stock. The piece of bark, with the bud in the centre, is then pushed under the sides of the cut, until the straight edge of the scion fits against the cross-bar of the T incision. The bud is then held firmly in place by binding with raffia or soft cord. This bandage should not cover the bud. After the bud has united with the stock, the binding is cut. This is done so that it may not interfere with the growth expansion of the stem or injure the bud.

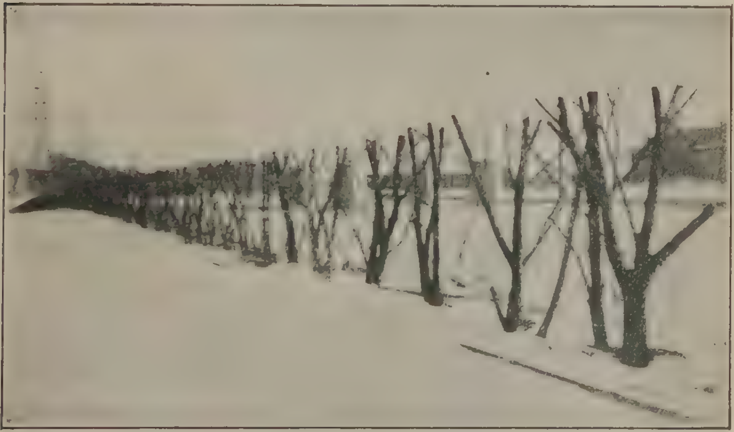


Fig. 169. Pollarded willows

Budding is becoming increasingly common. It has now almost supplanted grafting on most of the trees which bear stone fruits, and is frequently used on those of apples and pears. In growing roses, too, cultivated varieties are often budded on such wild species as the sweet briar.

Pruning.—When some parts of a plant are removed with a definite purpose, it is said to be pruned. Pruning has various uses: (1) As already pointed out, the roots and branches of a tree are often trimmed before being planted. The reducing of the crown is to prevent too rapid loss of water before the roots have commenced absorbing it. (2) Diseased parts of a plant are often removed to prevent the infection spreading to healthy tissues. (3) Any desired shape can be given to a tree or shrub by trimming. When willow trees are cut back, they are said to be pollarded. (See Figure 169.) This is usually done to thicken the crown of the tree, but some willows are cut back to ensure a plentiful supply of twigs for basket-making. (4) The removal of

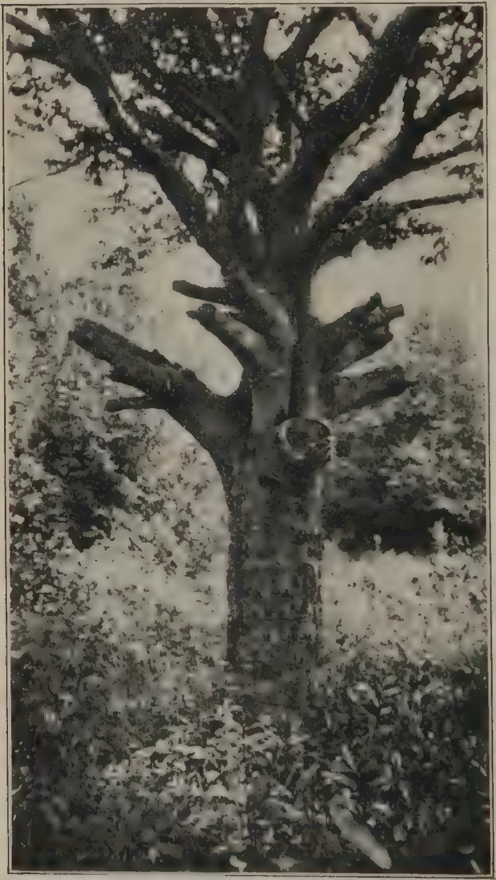


Fig. 170. Where will decay be apt to commence in this tree?

branches opens up a plant to admit sunlight and to permit a free circulation of air. By thus allowing fewer flowers or less fruit to develop, finer individual specimens are obtained. (5) By checking the growth of leaf and stem, the production of fruit is increased. Pruning is practised for this purpose in orchards. In the Niagara district the trees are kept relatively small, but much well-developed fruit is produced. The object of the pruner must always be to have as much food as possible go to the growth of the fruit, and only enough into leaf and stem to ensure a healthy, vigorous plant.

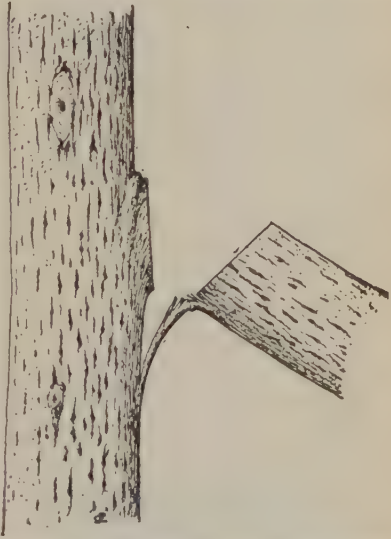


Fig. 171. An incorrect method of cutting off a limb

It is difficult to give rules for pruning, as these must differ with the individual plant and the desired result. There are, however, a few general principles of special application to fruit trees. It is advisable to prune each year, as then it is not necessary to remove large limbs. In this way, also, limbs growing in the wrong direction can be headed back when young. Two limbs that cross should not both be allowed to remain, nor should a limb that grows across from one side of the tree to the other.

The best time for pruning is just before the opening of the growing season. At that time the wounds made soon heal. Buds may be pruned off at any season. If a tree is producing wood too rapidly, summer pruning will check its growth.

Stubs should never be left when limbs are sawn off. The cut ends cannot heal over before decay sets in. To prevent a large limb from splitting back when it is removed, it should be cut off several inches out from the main branch. The stub can then be shortened. All cuts should be smoothed down as close to the main stem as possible. Large wounds left by the removal of limbs should be painted or covered with grafting wax.

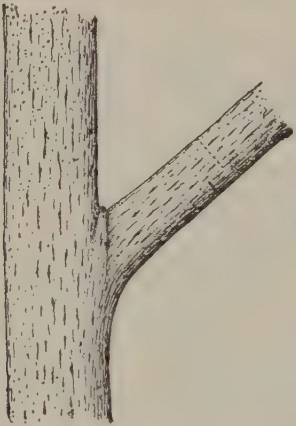


Fig. 172. The limb should be sawn off as indicated; the lower cut is made first.

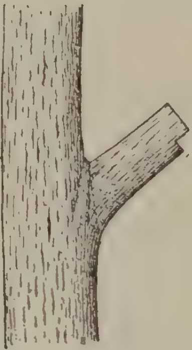


Fig. 173. The stub may then be trimmed closely and the cut surface smoothed down.

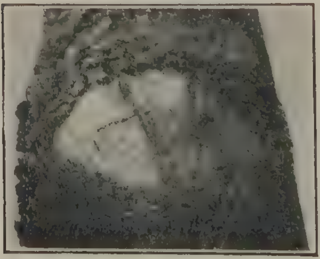


Fig. 174. A limb scar completely closed over

Fig. 175. A limb scar that has commenced to close over

CHAPTER XVIII

PLANTS AND PLANT PRODUCTS

Have you ever considered to what an extent we are dependent upon plants and plant products? If you have, you will agree that they are so necessary to us that it seems hardly possible that we could live without them. Throughout the whole day, from the time that we use our linen towels in the morning until we go to sleep between cotton sheets at night, these plant products are contributing to our health, comfort, and happiness. Our food is largely vegetable in nature; our houses consist, in part, of wood; our clothes are not altogether wool; even the papers and the books that we read are manufactured from wood pulp.

So essential are certain plants to man that he has devoted much time and thought to an effort to determine the best way of raising the useful ones. Before the white man reached the shores of Australia, there was not a single cultivated plant known in that country. The natives gathered a few seeds and dug up roots, especially those of the wild yam, a potato-like fruit. No attempt, however, was made to cultivate the plants. By the application of modern methods of farming, Australia has become one of the great agricultural countries of the world.

The natives who inhabit the mountains of the Philippine Islands have as yet taken only the first step in agriculture. They have progressed far enough to know that plants thrive better when they are not crowded and do not have to struggle for their existence. Accordingly, they clear away the jungle from around their huts, sow the food plants there, and endeavour to keep these garden plots free of weeds. They have also learned by experience that the same soil will not produce good plants year after year. Accordingly, every few years they move their huts and make new clearings where the soil is not exhausted.

In comparison with the natives of Australia and the mountain people of the Philippines, some of the African tribes are quite well versed in agricultural methods. The negroes of Uganda, for example, keep a number of domestic animals—cattle, goats, sheep, and fowls. They have also large plantations of bananas, and these they consider their most valued possession. The banana, indeed, is their staple article of diet. The early missionaries were accused of coming to Uganda solely for the bananas. This seemed the only logical reason to the natives, as there were no bananas in England, and they could not conceive of a people living without them.

Food plants.—It is interesting to consider where our food plants were originally cultivated. It is believed that the bananas in the African plantations were not produced by cultivation from the much inferior wild species growing in the surrounding jungle, but were cultivated to their fleshy, almost seedless condition in Asia, and from there spread to Africa. Many of our other food plants are known to have come from the Far East and from the countries about the eastern end of the Mediterranean basin. In those countries they must have been cultivated for many hundreds of years, until they have reached their present perfection. It was in the Far East that our so-called citrous fruits—oranges, lemons, grape-fruits, etc.—were first grown. The Japanese have erected a monument in honour of Tajima Mori, who first made a success of raising these fruits in Japan. He was set the task by the Mikado, and succeeded in bringing the plants from China and establishing them in his own country. All our food plants, however, are not from the East. Some, such as Indian corn, gourds, pumpkins, and potatoes, have originated in the warmer parts of the American continent.

As we have seen, nearly all our food plants have been introduced into this province. Many of our wild plants, however, bear edible fruit. In the Lake Erie district is found the papaw tree, the fruit of which averages over three inches in length. Its cylindrical shape, often curved, is suggestive of a banana. The fruit of the papaw is the largest of our edible wild fruits, but opinions differ concerning its flavour. One writer states that it is sweet and luscious; another that it can be enjoyed only by one who is very young or very hungry.

Some of the more common wild fruits that are "good to eat" are: strawberries and raspberries, which are not real berries at all, cranberries and huckleberries, which are regarded as botanical berries, and June berries, which are more like miniature apples than berries. These last are interesting because they were the principal berries that the squaws of the North American Indians pounded up with the buffalo meat to make pemmican.

Plant fibres.—Scarcely less important than the plant food products are the various fibres obtained from plants.

Linen.—As you know, the fibre from flax is used extensively for table linen, handkerchiefs, collars, and thread. Until comparatively recently, linen was used for clothing even more frequently than cotton; now, however, cotton is used almost exclusively for that purpose.

The fibre from which linen is manufactured is obtained from the stems of the flax plant. After threshing out the seed, the plants are steeped or retted. In North America this is done by spreading the bundles out evenly over a damp meadow. The flax is left there until the bast fibres, the part used, separate easily from the remaining tissues of the stem.

Cotton.—Cotton has to a great extent supplanted linen and is competing successfully with wool and silk. Flannelette, a pure cotton fabric, is being used commonly as a substitute for wool. Mercerised cotton can be made to resemble silk so closely that it is difficult to detect the difference.

The raw material for cotton consists of a white mass of large numbers of hairs attached to the seeds of the plants. In the more primitive plantations the fibre is pulled from the seeds by hand, but usually this is done by a machine known as a "gin." The seeds are used as a source of oil.

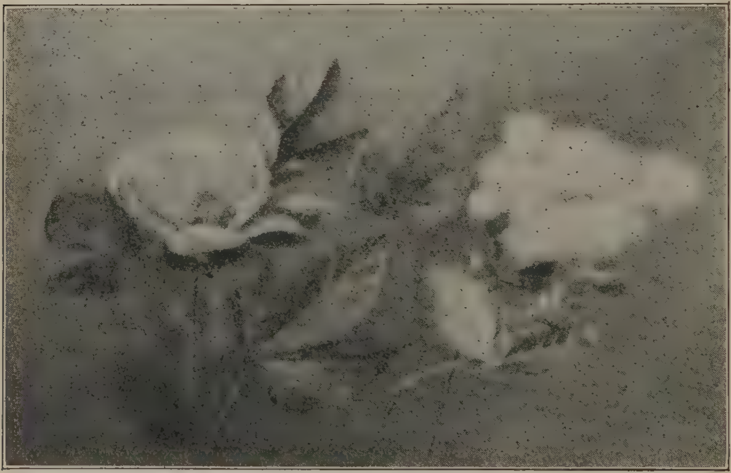


Fig. 176. A cotton plant with the boll developed

The cotton plant is closely related to the round-leaved mallows of the roadsides and the hollyhocks of the gardens. Indeed, the cotton plant, with its yellow, white, or red flowers, bears a close family resemblance to a hollyhock. Most of the species of the cotton plant are perennial in warm countries, but in the United States the plants are grown from seed each year.

The hemps.—There are many other vegetable fibres of commercial value. Among these are the hemps, such as sisal and Manila hemp. But the true hemp fibre is from a plant of the Nettle Family. As it has escaped from cultivation in Ontario, you will find its name (*Cannabis sativa*) in your flora. This hemp is now employed as a substitute for flax in the manufacture of ropes, twines, and fishing lines.

Sisal hemp.—There are different varieties of this hemp, but the best is said to come from Yucatan and the Bahamas. It consists of the fibrous part of the leaves of a plant resembling the cultivated century plant.

Manila hemp.—This is secured from a species of banana plant found in the Philippine Islands. The plant does not bear edible fruit. This is considered the best hemp for rope-making, especially for cables and hawsers and similar cordage.

Jute.—This well-known fibre is secured from a plant related to our basswood. It is used for ropes and twine, and is also manufactured into "gunny" sacks and bales for cotton.

Paper-making fibres.—Many grasses and other plants serve as a source of the raw material for paper. That out of which the Japanese manufacture their lanterns, parasols, and even books is from the fibre of a species of mulberry. Chinese rice paper is prepared from a plant related to the cultivated ginseng.

The source of the best paper-making fibre, however, is wood pulp obtained by reducing wood to a soft, pulpy mass. In this source we are very much interested, as the coniferous forests of the northern part of Ontario provide an important supply of raw material. Newsprint is manufactured from spruce, balsam, and jack pine; but the spruce is the most important source of pulp in Canada. By the soda-pulp process good paper is manufactured from the poplar.

Medicinal plants.—In the early ages it was currently believed that in plant products had been provided remedies for all diseases. The resemblance of any part of a certain plant to an organ of the body was regarded as nature's way of indicating that the plant would cure diseases of that organ. For example, a plant with a heart-shaped leaf should be the source of the remedy administered for heart disease. As the leaf of the common hepatica was supposed to resemble the liver, it was prescribed for diseases thought to originate in that organ. It is interesting to note that the hepatica still retains its common name of liverleaf.

This method of selecting the proper medicinal plant has, of course, been long discontinued, but a large number of plant products are still used in the practice of medicine. Among these products are quinine and belladonna, and also podophyllin, which is obtained from the rootstock of our common May apple. So many of such remedies are known at present that they have come to form an important branch of medical science.

CHAPTER XIX

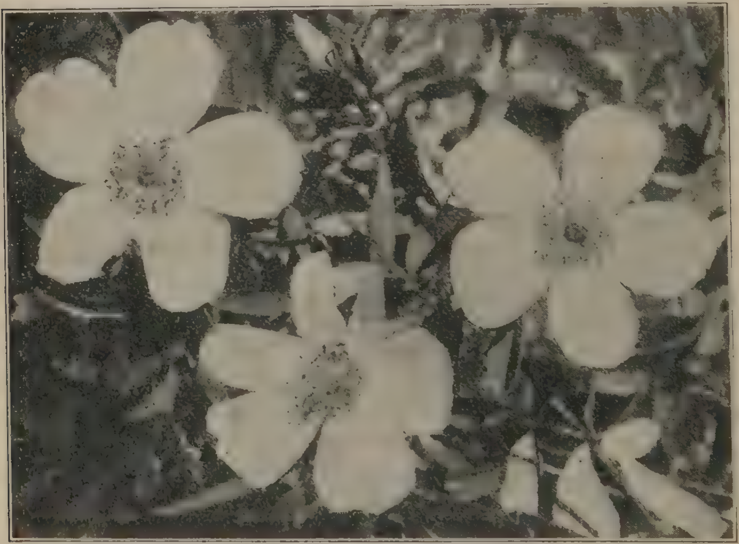
THE IMPROVEMENT OF PLANTS

Most of our food plants have been cultivated from such a remote age that we do not know the wild plants from which they have sprung. Our almost seedless banana is believed to have been derived from the wild banana, which has large, bitter seeds and tasteless pulp. To bring about such remarkable changes as have occurred in this instance, a great many years of cultivation must have been necessary, so many that their beginning reaches back before the days of written history.

Written records prove that very long ago people had grasped the first principles of improving cultivated plants. They understood that small seeds will not produce good plants. The Roman poet Virgil states in one of his poems that plants degenerate unless the largest seeds are sown. Other records show that the early Chinese tillers of the soil selected the best seed for sowing.

There is an interesting story told of a Scottish farmer who noticed in his field two or three heads of wheat which seemed unusually large. He kept these and planted the grains in a plot by themselves. He then planted the produce of his little crop, and continued to do this until he had enough of the wheat to put on the market. As the new variety had undoubtedly superior qualities, the farmers were anxious to procure it for seed. In a few years Hunter's wheat, as it was called, had spread over England and Scotland and was known even in France. Although this happened many years ago, Hunter's wheat is still popular in those countries.

This method of selection for obtaining new varieties of plants is still used. As no two plants are exactly alike, it is usually possible to obtain, among thousands, one or two that seem to have more desirable qualities than the others. If, each year for a number of years, seeds of these plants are sown and a selection of seed plants is again made, the new qualities will become permanent. The plants are then said to *reproduce true* from the seed.



Courtesy of William Connon, Toronto

Fig. 177. A common species of wild rose. From such single species double species have been produced by selection.

Results are obtained only very slowly by the process of selection. A speedier method now followed for producing new varieties is that of cross-pollination. This, as you remember, is placing the pollen from one flower on the stigma of another flower. In this case, different varieties or even species are crossed.

Artificial cross-pollination is not a difficult process, but it requires considerable care. Some of the pollen to be used is obtained by dusting it from the blossoms on to a paper. From a bud that is about to open the stamens are carefully removed, and some of the collected pollen is applied to the stigmas of the prepared flower. The pollinated flower is then covered to prevent other pollen from reaching its stigma. If seeds are produced and plants are grown from them, these are called "hybrids" or "crosses." A careful record should be kept of the two species crossed.

Luther Burbank, a Californian gardener, is probably the best known of plant breeders. He has been successful in making some curious hybrids between plants only distantly related, such as the apple and the blackberry; the petunia and the tobacco; the apple and the raspberry. These are only of scientific interest, but much of his work is of economic importance. His plum hybrids, obtained by crossing a stoneless wild plum with a French prune, have a commercial value.

The story of how he produced a crimson poppy from a wild species of a pure yellow colour will illustrate his methods of working by selection. These wild poppies are very abundant in California, and, always on the lookout for a new variety, Mr. Burbank saw, among the many, one poppy with a bright, crimson line sharply outlined on its yellow petals. He transplanted this variety into his nursery and obtained the seed from it. These seeds were sown, and all the plants that showed the bright crimson line in their flowers were again left for seed. For many plant generations he continued to select the poppies with the broadest crimson band and to plant the seed from them. The result was that with each succeeding generation the band gradually became broader, until at length it covered the whole of the petals, producing a pure crimson poppy.

Much work has been done in attempts to secure varieties of wheat adapted to the climates of different countries. The variety in which we, as Canadians, are the most interested is the Marquis wheat. In 1917, nearly 250,000,000 bushels of this wheat were raised in North America, and in 1918 the amount had increased to 300,000,000 bushels, which all originated in a single head picked by Dr. Charles E. Saunders in 1903.

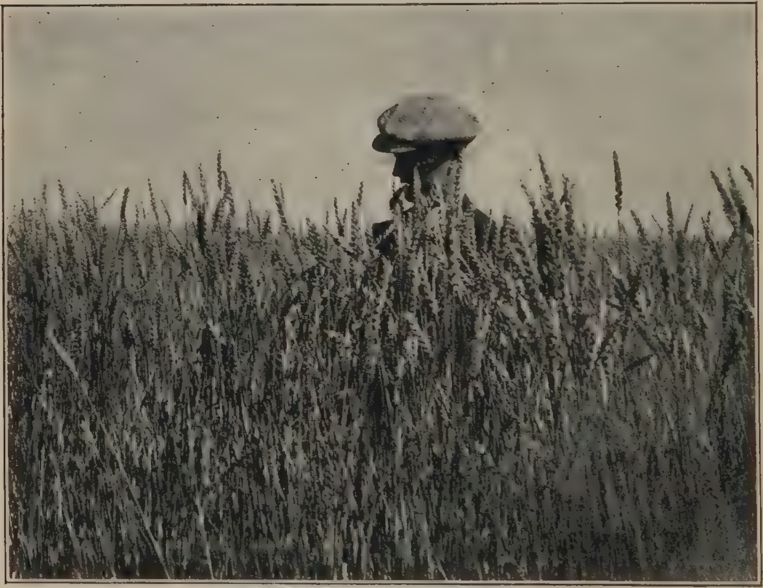


Fig. 178. A field of Marquis wheat

The discovery of the Marquis wheat forms a fascinating story of cross-pollination. Toward the close of the last century, the wheat known as Red Fife was planted almost exclusively by the farmers of Western Canada. This wheat was so good that its highest grade, Manitoba No. 1 Hard, had a world-wide reputation for its excellence.

Early frosts, however, are common in many parts of Canada, and, when these occurred, heavy losses were caused by the wheat freezing in the fields. In the years of frost, the farmers asked for an earlier-ripening wheat. To satisfy this demand, the late Dr. William Saunders, then Director of the Dominion Experimental Farms, imported several different kinds of wheat. He cultivated these with the Red Fife, in order to compare their times of ripening with it. Among these wheats were some brought from the colder parts of India and others from Northern Russia. One of the latter varieties, from Lake Ladoga north of Petrograd, seemed at first to offer a solution of the problem. It yielded well, and ripened about ten days earlier than the Red Fife, but flour ground from it was found to bake into an inferior bread.

When the imported varieties of wheat proved a failure, Dr. William Saunders tried by crossing many varieties to produce a satisfactory early-ripening wheat. In this he was assisted by his two sons, one of whom, Dr. Charles E. Saunders, was afterwards appointed director of the work of wheat breeding for the Dominion. While in this position Dr. Charles Saunders worked over the various crosses which had been made earlier. By doing this he obtained a large number of strains, and among these discovered what we know now as the Marquis wheat.

On looking up the records, the variety was found to have arisen from crossing Red Fife with an early ripening Indian wheat called Hard Red Calcutta. From the first seeding of Marquis Dr. Saunders obtained only twelve plants, but the produce from this small harvest now fills the elevators of our Western Provinces.

At the Ontario Agricultural College, Guelph, much work has been done in hybridization and selection. These experiments have yielded new varieties of field grains with a combination of desirable qualities. Of these grains may be mentioned—The O.A.C. No. 72 variety of oats, the O.A.C. No. 104 variety of wheat, and the O.A.C. No. 181 variety of field peas.

Experiments at the Ontario Agricultural College have been successful in the production not only of improved grain crops but also of new varieties of flowers and fruits. A lily obtained by such experiments is said by authorities in the United States to be the finest hardy lily in existence to-day.

The Canadian tomato, another discovery, is an early variety, and a good shipper. A strawberry known as the O.A.C. No. 4258 is being planted extensively in Western Ontario, and with good results. Promising varieties of apples have been obtained by crossing the McIntosh Red apple with the Northern Spy and with the Wealthy.

CHAPTER XX

SPRING PLANTS

The charm of our early spring flowers always awakens a feeling of surprise that anything so frail and delicate-looking as they should follow so closely upon the frost and resulting desolation of winter. No sooner does the snow disappear from the wooded southerly slopes than, in many sheltered nooks, the buds of the hepatica and the trailing arbutus (Fig. 179) begin to peep out from under their winter covering of leaves. The frost is scarcely out of the rich, black loam of the low-lying grounds before the spring cress

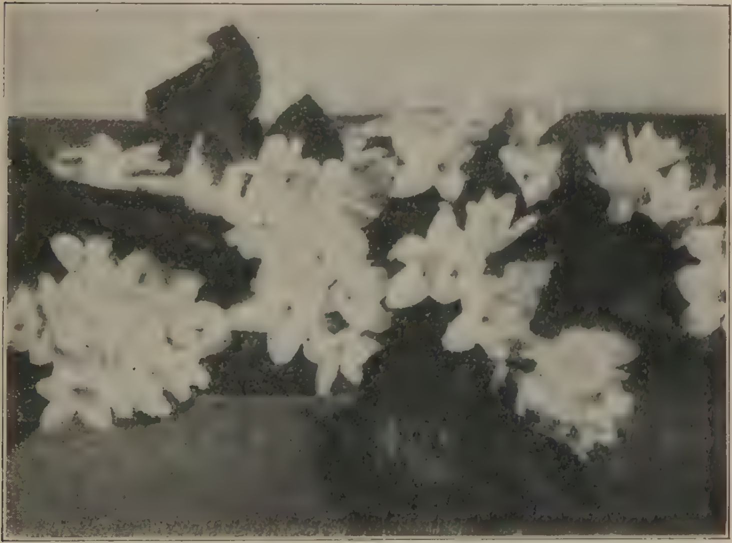


Fig. 179. Trailing arbutus

and the spring beauty are closely rivalling each other in the early-flowering competition. These flowers are in bloom almost before the alder tassels are scattering their pollen and the buds are awakening on the red maples.

The early appearance of the flowers that in the spring so plentifully dot the floor of the woods is possible only because of the perfect preparation made by them during the preceding season. Everything is ready for the vitalizing influence of the spring sun. During October and early November the flower buds are swelling on the trailing arbutus, and at the same season the cowl of the skunk cabbage (Fig. 180) can be found only a short distance below the surface of the soil or even with its tip projecting above it. The flowers that appear early in the spring have also the supplies of food necessary for the prompt resuming of growth activity. These stores of nourishment have been safely hidden during the winter in bulbs, in rootstocks, and even in the ordinary roots.

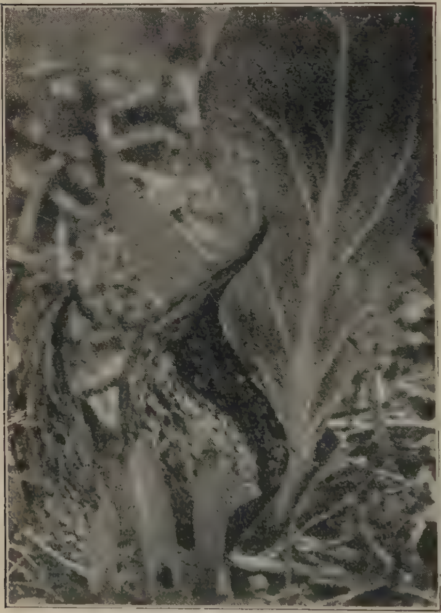
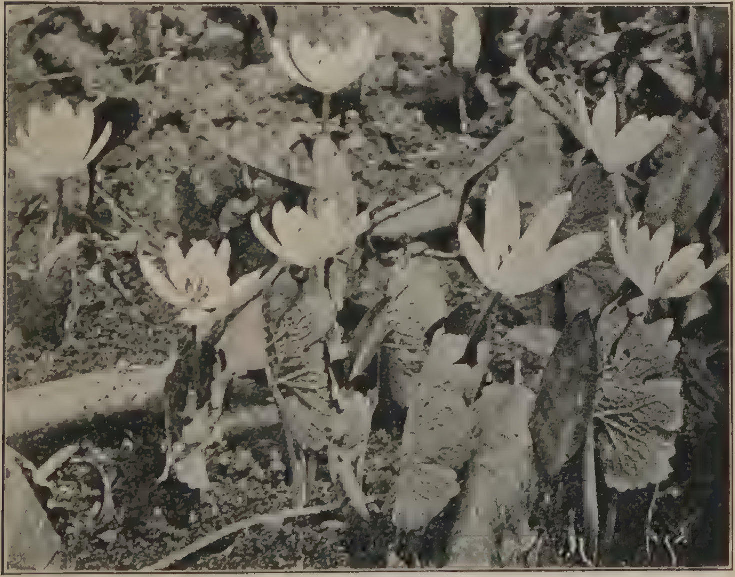


Fig. 180. Skunk cabbage

Since nearly all our early-flowering plants are woodland dwellers, their prompt appearance in the spring is a necessity. If the time of flowering is delayed too long, the foliage of the over-arching trees will have become so thick that not enough sunlight can filter through to mature the fruit of the shaded plants. Thoreau observed that it was only those plants that require but little light that prefer to dwell in the woods. But it is also equally true that such plants are able so to hasten their flowering that it is completed before the shade becomes dense enough to shut out the sunlight.



—*Courtesy of United Church Publishing House, Toronto*

Fig. 181. Blood-roots. To what fact does this plant owe its name?

The flowers of our spring plants appear with the leaves or often before them. The period of blossoming is not postponed even for the important one of leaf production, as in the summer and autumn plants.

The early-appearing plants have various devices that protect them in the fickle spring weather. The annuals are nearly all low plants. They hug the ground so closely for warmth that some of them scarcely show above the leaf carpet of the woods. The flowers of many of them are inclosed, like those of the hepatica, in hairy bracts. Others are shielded from cold winds by their own developing leaves. The solitary bud of the blood-root (Fig. 181), until it is ready to burst, is snugly enrolled in its leaf, which does not unfold until the plant's time of flowering is past. One, at least, of our early spring flowers, the spring beauty, has adopted the plan of closing its blossoms in cloudy or stormy weather to shield the pollen from the frequent showers of spring.

Fig. 182. Fringed gentian, one of the typically blue flowers of autumn

Since they are growing under similar conditions, the plants of polar regions and mountain tops resemble closely our spring flowers. Many of them have the same means of defence against the cold. They have the common low habit of growth and the protective covering of hairs or scales. The short growing season, also, makes it necessary for the polar plants to blossom early, in order to ripen their fruits before the close of the summer.

In general, the spring flowers are simple in structure. They do not present the complicated devices by which so many of the summer and autumn flowers gently compel their insect guests to carry on the work of conveying pollen from one flower to another. Few of the spring plants have learned the advantage of combined effort; there are scarcely any of them in which the flowers are closely clustered. In many of the autumn plants the blossoms are formed into communities in which a perfect division of labour has been developed. The showy circles of flowers around the heads of the asters do not produce seed, but they serve to entice the insects that carry the fertilizing pollen to the seed-producing flowers in the centres of the colonies.

STUDY OF THE COMMON TULIP
(*Tulipa Duc Van Thol*)

While the tall buttercup, the mustard, and the aster are types of the dicotyledons, the tulip is typical of the monocotyledons. In place of this tulip may be substituted any one of the many varieties of tulips, or one of the following—lily, crocus, snowdrop, trillium, or dog's-tooth violet.

This common, cultivated plant has been introduced from Asia Minor. It flowers early in the spring from bulbs planted the preceding fall.

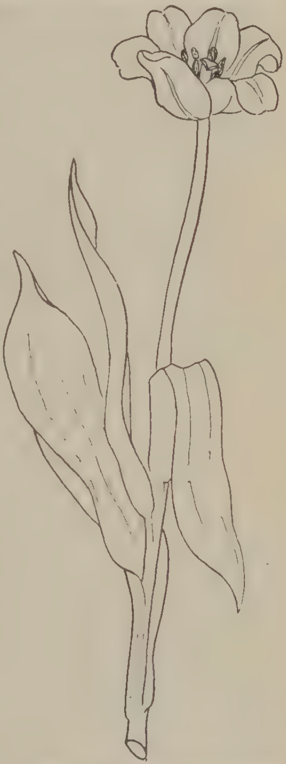


Fig. 183. The common tulip with the flower open

Flower.—The erect, bell-shaped flower is borne at the top of a pubescent *peduncle*. This is an example of *solitary* inflorescence of the *terminal* type. The tulip has not a green calyx, but its floral leaves are arranged in two whorls, an outer and an inner, of three each. The term perianth, however, is usually applied to the floral envelopes of all such flowers as the tulip. This seems advisable, as there is not a clear distinction in colour between calyx and corolla. The perianth of the tulip is usually white, red, or yellow, but it may be variegated. This species is red in colour, with a yellow "eye" that includes about one-third of the height of the perianth. Since the floral leaves are quite separate one from another, the term *polyphyllous* is applied to the perianth. In such a flower as the lily of the valley, in which the floral leaves are connected, the term *gamophyllous* is used. As the perianth is attached to the receptacle, below and free from the ovary, it is inferior.

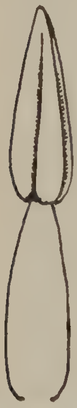


Fig. 184. The stamen of the common tulip

There are six stamens, one in front of each division of the perianth. They are attached to the receptacle (hypogynous). The filaments and anthers of the stamens are nearly equal in length, each about one-half to three-quarters of an inch. The filaments are flat, are broad at the bases, and taper to points. The anthers are as wide as, or wider than, the filaments, and are yellowish and awl-shaped at the tops. The anther cells split longitudinally on the outside and open out flat to set free the pollen. (See Figure 184.)

The pistil consists of three parts. The stigma has three narrow lobes, the style is very short, and the ovary is three-angled. The ovary, when cut across, is seen to be three-celled and is, therefore, syncarpous, consisting of three united carpels. (See Figure 185.) As in the mustard, which we have already studied (page 15) the ovary is superior, free from the calyx.

The capsule, also, is three-celled, or occasionally four-celled when the perianth is in fours. The seeds, which are in two rows in each cell, are thin, flat, and packed closely, one above the other in each row.

Stem.—At the lower end of the stem and surrounding it, is a bulb (Fig. 186). This consists of several layers of thickened leaves. The stem passes up from the base of the bulb, through its centre, and merges with the peduncle. On the outside of the bulb is a thin, heavily-veined layer that is brown in colour and scale-like.

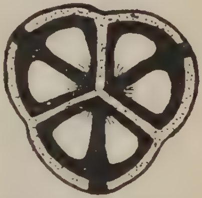


Fig. 185. A section of the ovary of the common tulip

Leaves.—The leaves are three to six in number. They are characterized by the following description: Alternate; sheathing stem, or nearly so; sessile; fleshy; straight-veined, oblanceolate, terminating in a short, blunt point; light green in colour.

Roots.—The roots of the tulip arise from the base of the bulb and are white and fibrous.

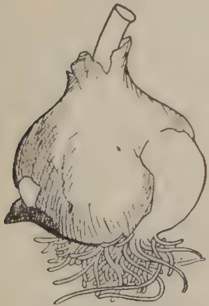


Fig. 186. The bulb of the common tulip

Classification. — The tulip is a type of a large family of plants known as the *Lily Family* or *Liliaceae.* To it belong many of our common cultivated plants, such as lily of the valley, jonquil, hyacinth, etc.; and wild species such as bellwort, Solomon's seal, clintonia, trillium, dog's-tooth violet, etc.

As a rule, the members of this family blossom in the spring or early summer. They come quickly to maturity, as practically all of them spring from bulbs or rootstocks, which contain starch and sugar sufficient to furnish the necessary food supply as soon as growth is possible.

All the members of this family possess the following distinguishing characteristics:

1. The flowers are regular and symmetrical, with their parts almost invariably in whorls of threes. The perianth and stamens each consist of two such whorls.

2. The stamens are six in number, with only one exception, in which there are four.

3. The ovary is chiefly three-celled and superior, that is, not united to the perianth.

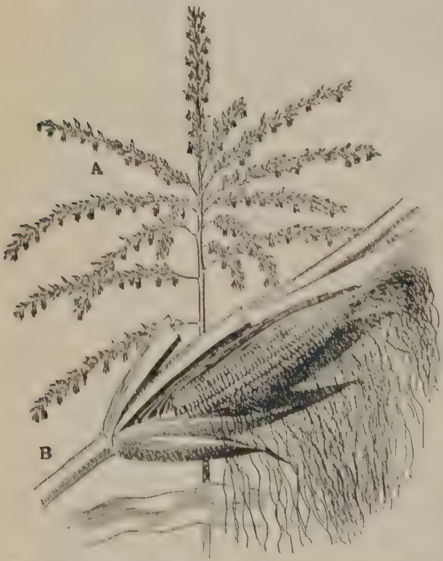


Fig. 187. A, a tassel of corn; B, an ear in the silk stage

THE GRASS FAMILY

Although a number of troublesome weeds, such as wild oats and the foxtails, are members of this family, it includes many valuable plants; so many, indeed, that the grasses are regarded as the largest and most important family of flowering plants. There occur in it not only such food plants as wheat, oats, rice, etc., but also many pasture and fodder plants, such as corn, timothy, and the millets.

The grasses are apt to escape our attention as their flowers are quite inconspicuous. You will recall the statement made on page 27 that the grasses are wind-pollinated and do not produce brightly coloured flowers that attract insects.

The grass flower has stamens and a pistil similar to those of the other flowering plants; but these organs are inclosed by small, green, leaf-like bodies, known as *glumes* (Fig. 188). These have the protective functions of the calyx and corolla.

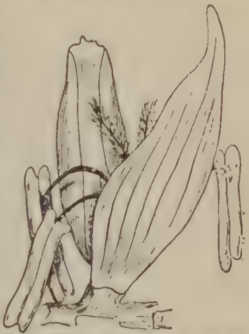


Fig. 188. A flower of wheat inclosed in its two scaly bracts or glumes

The stem of the grass is cylindrical and hollow, except at the joints, which are solid. The corn stem is an exception to this, however, as it is solid throughout.

The leaves are usually long, tapering, and parallel-veined. Each leaf has a sheath that surrounds the stem like a tube. The sheath is split on the side opposite the blade, and the lining is prolonged above its line of union with the stem.

THE SEDGES

The sedges, often mistaken for grasses, are distinguished from the grasses by having the sheath entire, and the stem usually triangular.

APPENDIX I

THE LANGUAGE OF BOTANY

In the plants which we have studied we have had examples of the use of terms. They provide us with a shorthand of botany that makes the descriptive work much briefer. For example, the term *tetradynamous*, used in the description of the wild mustard, is the equivalent of the statement that the stamens are six in number, four of them longer than the other two.

The terms introduced in this Appendix are some of the more common terms used in the description and identification of plants.

FLOWERS

As the common classification of plants is based on the structure of the flowers, the terms used in describing them are very important.

We have already seen that the flower consists of *calyx*, *corolla*, *stamens*, and *pistil*. The calyx and the corolla together are known as the *floral envelope* or *perianth*. These terms are very useful in the description of flowers such as our lilies, where it is difficult to distinguish between the two whorls. Since the stamens and the pistil are the seed-producing parts of the flower, they are often called the *essential organs*. The swollen end of the stem, known as the *receptacle*, on which the flower is borne, is considered as almost another part of the flower.

In some flowers the four parts are not all present, and certain terms are used to indicate this. A flower that has both stamens and pistil developed is *perfect*, as it has the organs necessary to produce seed. If either of the essential parts is absent, the flower is *imperfect*: it cannot alone produce seed. An imperfect flower that has only the stamens present is *staminate* (Fig. 189); one that has only the pistil present is *pistillate* (Fig. 189); and, when both of these organs are absent, the term *neutral* is used. If the staminate and pistillate flowers are on the same plant, we say that it is *monoecious*; but, if these flowers are on different plants, the term *dioecious* is used. To illustrate the two last terms—the flowers of the Indian corn are borne on the same plant, the staminate forming the tassel at the top of the stem and the pistillate the cob, while the two types of flowers of the willows and the poplars are on different plants.

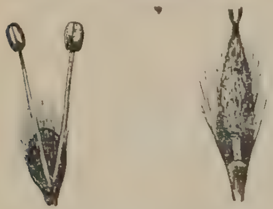


Fig. 189. On the left is shown the staminate flower of a willow; on the right, the pistillate flower of a willow.

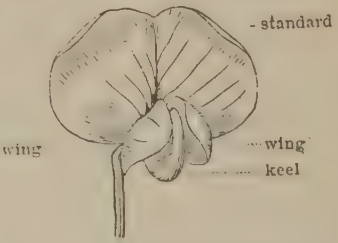


Fig. 190. The irregular flower of the sweet pea

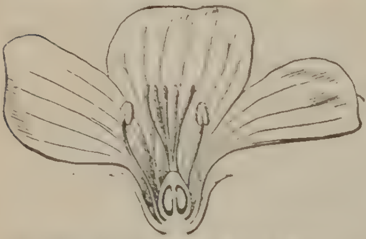


Fig. 191. An inferior calyx and a superior pistil, as in the flower of the flax

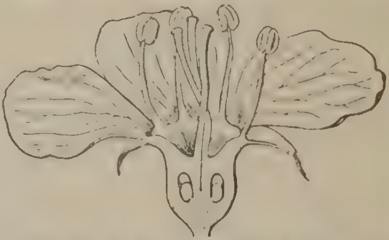


Fig. 192. A superior calyx and an inferior pistil, as in the flower of the hawthorn

If the different members of each whorl of the flowers are practically alike in size and shape, as in the buttercups, the flowers are said to be *regular*. If the members of the whorls differ from each other, as in the mints and the orchids, the flowers are said to be *irregular*. (See Figure 190.)

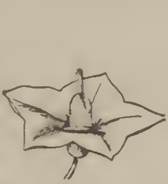


Fig. 193. A rotate corolla, as in the flower of the common potato

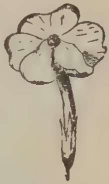


Fig. 194. A salver-shaped corolla, as in the flower of the phlox

Calyx.—When the sepals are entirely separate from one another so that one can be pulled off without disturbing the others, the term *polysepalous* is applied to the calyx; but, if there is any union between the sepals, the calyx is said to be *gamosepalous*. Also, certain terms are used to indicate the relation of the calyx to the ovary. A calyx that is attached below the ovary and free from it is *inferior* (Fig. 191), while one that is grown fast to the ovary and rises above it is *superior* (Fig. 192).

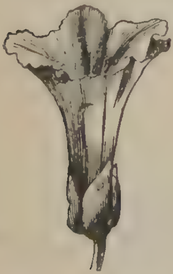


Fig. 195. A funnel-shaped corolla, as in the flower of the morning glory or bindweed

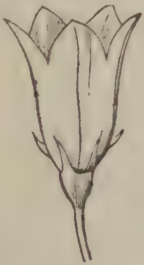


Fig. 196. A campanulate or bell-shaped corolla, as in the flower of the bluebell

Corolla.—The relation between the petals is indicated by terms similar to those applied to the calyx. When the petals are separate, the corolla is *polypetalous*; but, if the petals are at all united, it is *gamopetalous*.

A gamopetalous corolla does not always have the same form. If it has a short tube with spreading border, it is known as a *rotate* corolla (Fig. 193). One that spreads out gradually into a wide border, as in the flower of the morning glory, is *funnel-shaped* (Fig. 195). If the corolla is rather short and only slightly spreading, as that of the bluebell, it is *campanulate* or *bell-shaped* (Fig. 196). When the corolla forms a long, narrow tube, with a border at right angles, as illustrated in the phlox, it is *salver-shaped* (Fig. 194). If distinctly two-lipped, as in the turtle-head or the snapdragon, the corolla is *labiate* (Fig. 197).

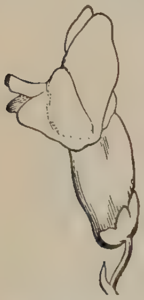


Fig. 197. A labiate or two-lipped corolla, as in the flower of the snapdragon

The place of attachment of the corolla is important. If borne on the receptacle, it is *hypogynous*; if on the calyx, *perigynous* (Fig. 198); and, if inserted on the top of the ovary or apparently so, *epigynous* (Fig. 199).

Stamens.—When stamens number more than ten, the botanist does not state the number, but considers that they are *indefinite* or *numerous* and indicates this by the sign of infinity (∞). If these stamens are separate and of the same length, the term *polyandrous* is applied to them. When the stamens are of any number up to ten, and are separate and of the same length, the term used is formed by placing before the ending *androus* the correct Greek prefix, thus: *triandrous*, *pentandrous*, *hexandrous*, *decandrous*, etc.

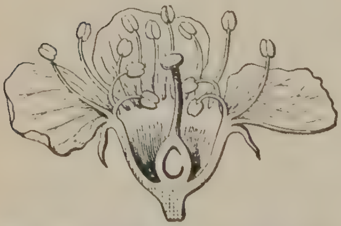


Fig. 198. A perigynous corolla and stamens, as in the flower of the cherry

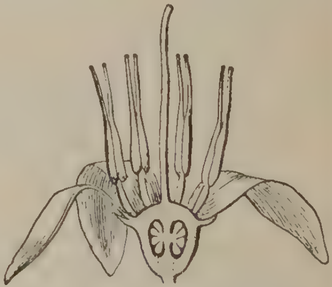


Fig. 199. An epigynous corolla and stamens, as in the flower of the cranberry

Stamens, however, are not always separate and of the same length. If there are four stamens, two longer than the other two, as in Figure 200, the term *didynamous* is applied to them; if six stamens, four longer than the other two, *tetradynamous*. When the filaments are united to form a tube, leaving the anthers separate, as in Figure 201, *monadelphous* is used and, if there are two sets formed by the union of the filaments, as in Figure 202, *diadelphous*. In our study of the aster we found that the anthers were united and the filaments separate; stamens of this type are *syngenesious*. (See Figure 204.)

The stamens may be attached to the receptacle, the calyx, or the ovary. In this, their insertion is the same as that of the corolla, and the same terms are used. The stamens may also be inserted on the corolla and are then *epipetalous*.

Pistil.—Just as the calyx consists of sepals and the corolla of petals, the pistil is made up of one or more carpels. If the carpels are separate or if there is only one carpel, the pistil is *apocarpous*; but, if they are united, as shown in Figure 209, it is *syncarpous*.

We have seen that a calyx is designated *inferior* when free from the ovary; in that case the ovary is said to be *superior*. From analogy, we must consider an ovary that has a calyx grown fast to it *inferior*.

Inflorescence.—The manner in which the flowers are arranged on a stem is called the *inflorescence*. Occasionally the term is used to mean the flowering part of a plant. Sometimes, as in the morning glory, the flowers are produced singly in the axils of ordinary leaves, but usually several or many flowers are massed together to form a cluster. In the cases where grouping occurs, the leaves are represented only by bracts or are absent altogether.

There are two quite distinct types of flower clusters. If a flower is produced on the end of a stem, the growth of

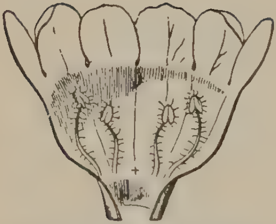


Fig. 200. Didynamous stamens that are epipetalous

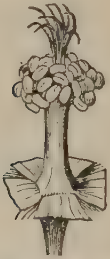


Fig. 201. Monadelphous stamens, as in the flower of the mallow

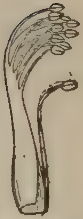


Fig. 202. Diadelphous stamens as in the flower of the sweet pea

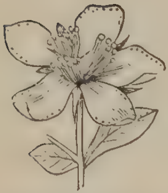


Fig. 203. Triadelphous stamens, in three groups, as in the flower of a St. John's wort

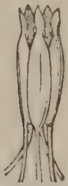


Fig. 204. Syngenesious stamens

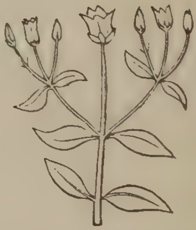


Fig. 205. A cyme

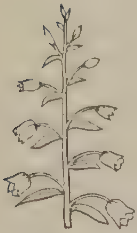


Fig. 206. A raceme

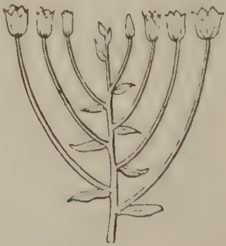


Fig. 207. A corymb

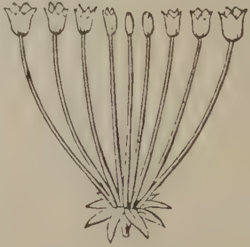


Fig. 208. An umbel

which is thus stopped, the remaining flowers must arise from buds lower down. The term *cyme* is applied to such a cluster, which is an example of *determinate inflorescence.* (See Figure 205.) The sweet william and the elder have their flowers grouped in this manner. In marked contrast with this is the cluster that arises when the stem continues to elongate and produce flowers, one in the axil of each bract. In this cluster the lower flowers open first. A cluster so formed is known as a *raceme* (Fig. 206). It is an example of the *indeterminate* type of inflorescence and is well illustrated in the red currant and the shepherd's purse. When the flowers of a raceme are very much crowded and are sessile or nearly so, a *spike* is formed. This may be seen in the plantain. If the axis of a spike is flexible, and the usually imperfect flowers are in the axils of scale-like bracts, a cluster, called a *catkin,* is formed. (See Figure 210.) Many of our common trees, such as the willow, the alder, and the poplar, bear their flowers in catkins. If the axis of a spike is very short and the flowers are necessarily crowded, the cluster becomes a *head.* We are already familiar with this cluster in the aster. If the main stem of a raceme elongates at about the same rate as the stalks of the lower

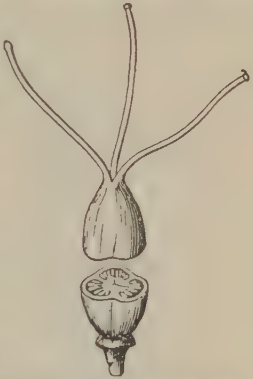


Fig. 209. A syncarpous pistil, as in the flower of a St. John's wort

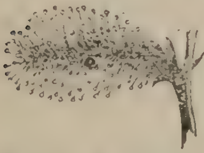


Fig. 210. A catkin of the willow

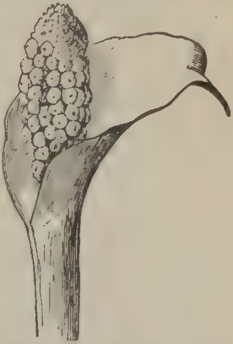


Fig. 211. The spathe and the spadix of the marsh calla

flowers, a flat-topped cluster or *corymb* is produced. (See Figure 207.) Examples of this are found in the hawthorn and the candytuft. If the main stem elongates very little, with the result that the pedicels of all the flowers spring from nearly the same point and are of equal length, or nearly so, an *umbel* results, as in the carrot or the parsnip. (See Figure 208.) If the axis of a spike becomes fleshy and the bracts are represented by a large showy one that in some cases may be absent, we have a type of inflorescence called a *spadix*. Its surrounding bract is a *spathe*. (See Figures 211 and 212.) Well-known examples of this are the Jack-in-the-pulpit or Indian turnip, the marsh calla or the water arum, and the cultivated calla lily.

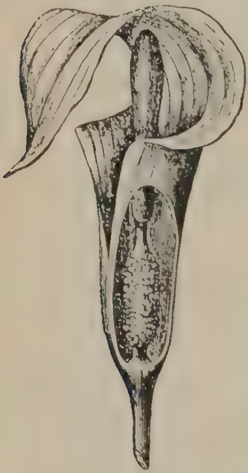


Fig. 212. The spathe of the Indian turnip, cut open to show the spadix

The term *solitary* is used in each type of inflorescence. Such a flower as the tulip is solitary of the *determinate* type, as it terminates the end of the stem. But the morning glory is solitary of the *indeterminate* type, as its flowers are produced singly in the axils of the leaves.

STEMS

The examination of plants will show that stems exhibit many different habits of growth and modifications of form.

Duration.—Numerous plants, such as the wild mustard, complete their full growth and produce their seeds in one season. These plants are called *annuals*. To this class belong some of our most troublesome weeds, such as pigweed, ragweed, lamb's quarters, purslane, etc. The great majority of plants, however, live on for many years, as do dandelions, thistles, yarrow, and our many trees. Such plants are known as *perennials.* But many of our native plants and a number of our vegetables live for two years and are, therefore, *biennials.* They lay up a supply of nourishment during the first season of growth, to be used by the plant mainly for the production of flowers and seeds in the second year. The burdock, the evening primrose, the carrot, the cabbage, the turnip, the parsnip, and many other plants are examples of biennials.

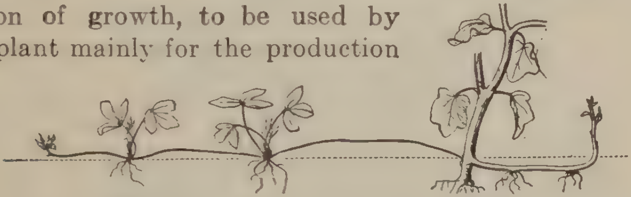


Fig. 213. A runner or creeping stem at the left

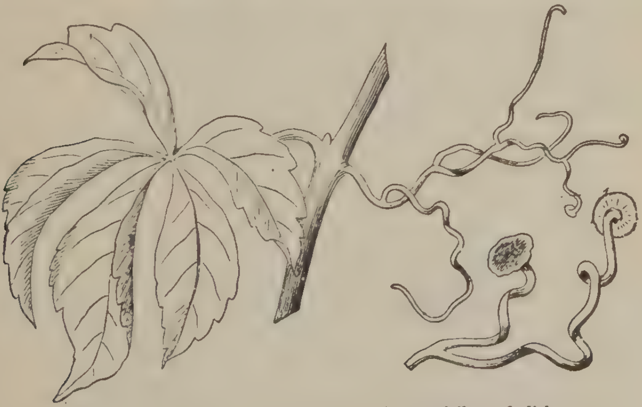


Fig. 214. Virginia creeper climbing by tendrils and disks

Directions of growth and position.—In direction of growth and in position, plants vary to a considerable extent. The following are some of the terms used in this connection:

Erect.—Growing upright, as the tall buttercup or the wild mustard.

Ascending.—Growing obliquely upwards.

Prostrate or procumbent.—Growing flat along the ground, as the melon, the cucumber, etc.

Diffuse.—Spreading in all directions, as the sweet alyssum, the purslane, etc.

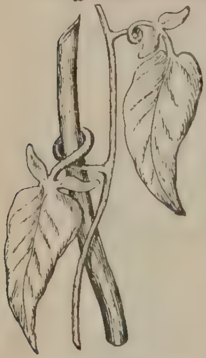


Fig. 215. A plant climbing by means of its leaf stalks

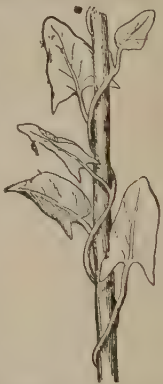


Fig. 216. A twining plant

Creeping.—Prostrate and striking root at intervals as the stem lengthens, as the ground ivy, the strawberry, etc. (See Figure 213.)

Climbing.—Some plants have the power to pull themselves upwards as they grow, thereby securing the advantage of more sunlight and air. They do this by one of several methods: (1) By means of *tendrils* developed from branches, as in the Virginia creeper (Fig. 214), or from leaves, as in the pea; (2) by *disks*, which adhere to the surfaces of walls, etc., as in the Boston ivy; (3) by *hooks* or *prickles*, consisting of modified hairs, as in the cleavers or the climbing rose; (4) by *leaf stalks* (Fig. 215) winding about various supports, as in the clematis and the bitter-sweet (*Solanum*); (5) by the whole plant stem twining about other stems, strings, etc., as in the morning glory and the hop. (See Figure 216.)

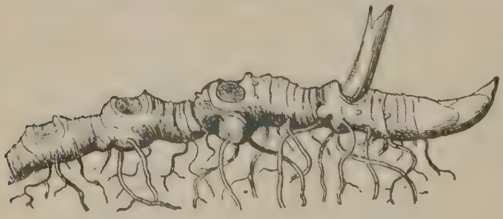


Fig. 217. A rootstock

Subterranean stems.—For purposes of protection from cold, heat, drought, etc., some plants have their main stems or main parts of their stems growing under the ground. There are several distinct types of such stems:

1. *Rhizome* or *rootstock.*—A thickened, usually horizontal stem that produces an annual bud at its extremity from which the aerial stem of the plant grows, as in the underground stems of blood-root, Solomon's seal, trillium, fern, etc. (See Figure 217.)

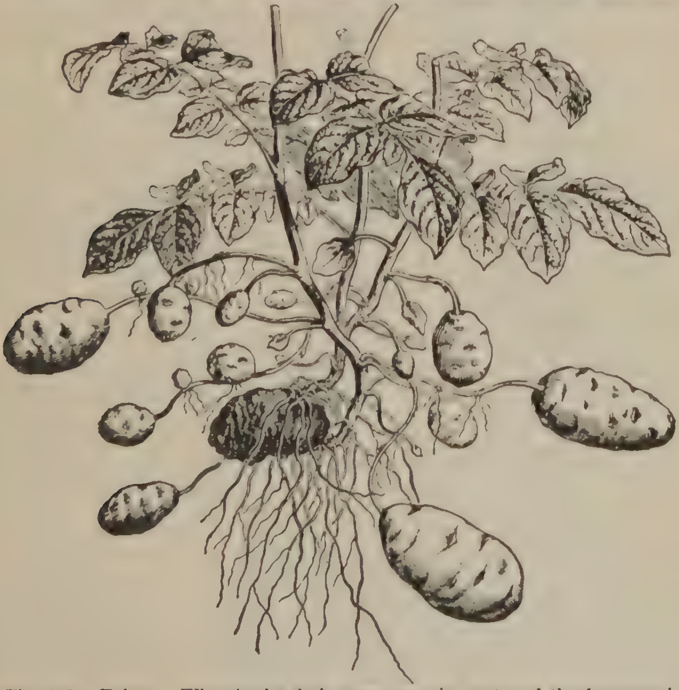


Fig. 218. Tubers. What is the dark mass near the centre of the foreground of the picture?

2. *Tuber.*—A very short, thick, starchy rootstock, covered by a thin skin, and showing one or more buds in the form of "eyes," as in the potato and the artichoke. (See Figure 218.)

3. *Bulb.*—An erect underground stem, the single bud of which is surrounded and protected by thickened, overlapping scales, as in the lily, or completely inclosed by the enlarged, fleshy bases of the leaves, as in the onion, the hyacinth, the tulip, etc. (See Figures 219 and 220.)

4. *Corm.*—The enlarged base of the underground part of a stem, resembling a bulb but more solid and covered with thin, loose layers, as seen in the gladiolus, the crocus, the cyclamen, and the Indian turnip. (See Figures 221 and 222.)

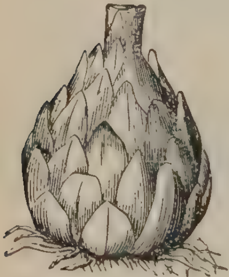


Fig. 219. A lily bulb

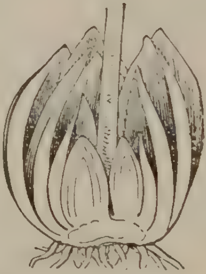


Fig. 220. A section of the lily bulb

5. *Sucker.*—A horizontal branch, which grows out underground from the base of the aerial stem and appears at the surface some distance away, as in roses, spearmint, etc. This term is applied by some to long, slender shoots which arise from dormant or from adventitious buds along the stem or branches. They are said to be the result of severe pruning or of an excessive supply of water at the roots. Such shoots, being very vigorous, rob the main branches of their normal water supply. As a result, they often dry up and die. Others apply the term to stems arising from adventitious buds on roots a short distance below the

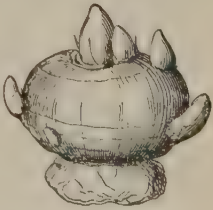


Fig. 221. The corm or solid bulb of a crocus

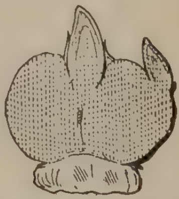


Fig. 222. A section of the corm of the crocus

surface of the soil. These occur some distance from the main stem, and often form a colony of young plants about the parent one, as seen in the Carolina poplar.

Secondary stems or branches.—Plants vary in their methods of branching as follows:

Simple.—This term is used when there are no branches and the stem consists of a continuous axis, as in the mullein, the tulip, the hollyhock, etc.

Excurrent.—A main axis or trunk can be followed through from the bottom to the top, the branches usually growing in consecutive whorls or layers, as in the spruce, the pine, and conifers generally.

Deliquescent.—The main stem soon divides, forming branches, as seen in the maple, the elm, etc.

Branches in some plants become stunted, and develop hard, sharp points which are called *thorns*. Examples of this type are found in the hawthorn, the honey-locust, etc.

In plants like the dandelion, where branches are wanting and the stem is very short, the term *acaulescent* is used. Such plants appear to be *stemless*.

Juice.—When plants have juice with a characteristic taste or colour, these should be noted. It is well known that the juice of the blood-root is red and that of the milkweed and the dandelion is milky; also that the juice of the celandine is yellow and that of the sorrel is colourless and sour.

Surface.—On the surface of both stems and branches are usually found outgrowths. When these are fine and of a soft texture, they are recognized as *hairs*; but when they are somewhat stiff, as on the rose and the thistle, they are known as *spines*.

Shape.—The majority of stems are *cylindrical*, but all mints have *square* stems, a great many sedges have *triangular* ones, and, as already mentioned, the stem of the wild mustard is *grooved*, while that of the sweet pea is *winged*.

LEAVES

Of all the organs of which plants are composed, leaves show the greatest variety of form and relation. Consequently, there are many more botanical terms used in describing the leaf than in describing any other part of a plant. Only those in common use are explained here.

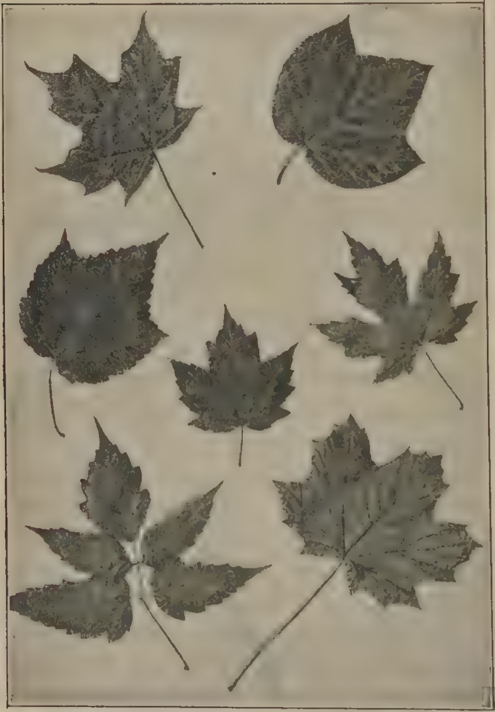


Fig. 223. Leaves of maples that grow in Ontario. How many species can you name from these leaves?

Arrangement.—Leaves are attached to the plant stem by various methods of arrangement. An examination of plants will show that their leaves are inserted with some degree of regularity. When the leaves occur singly at different levels on the stem, the arrangement is described as *alternate.* (See Figure 6.) When two leaves are at the same level and placed opposite to each other, the arrangement is *opposite* (Fig. 224). When three or more leaves grow in a circle about the stem, they are described as *whorled.* In the case of a few plants, such as the pines, the leaves grow in bunches or clusters of two or more, from points along the stems. This is termed a *fascicled* arrangement (Fig. 225).

Parts.—A typical leaf comprises three distinct parts: (1) the *blade*, a usually thin portion with a relatively large amount of surface, (2) the *stem* or *petiole*, and (3) two *stipules*, the latter resembling minute blades or outgrowths, one on either side at the base of the leaf stem. (See Figure 226.) When these stipules are absent, as in the case of many kinds of leaves, the leaf is said to be *exstipulate;* and, when the petiole is absent, the leaf is *sessile*.

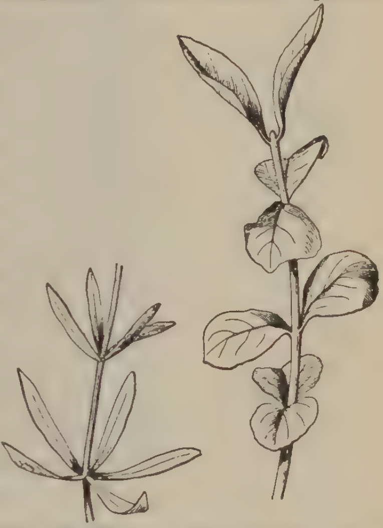


Fig. 224. Whorled and opposite arrangement of leaves

Division.—If the blade of any leaf is all in one piece, though it may be variously cut or indented on the margin, it is termed a *simple* leaf (Fig. 228). If the blade is composed of more than one piece, thus forming *leaflets*, it is known as a *compound* leaf. If these leaflets all arise from the same point at the end of the main petiole, the leaf is *palmately* compound (Fig. 229); if from different points along both sides of a main midrib, it is *pinnately* compound (Fig. 227).

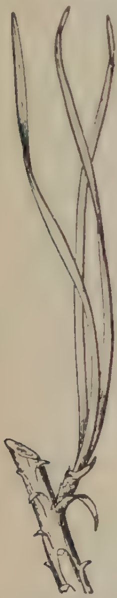


Fig. 225. Clustered or fascicled leaves of a pine. These leaves are from a pitch pine, but any other pine will show clustered leaves.

Venation.—The following are the common methods of venation:

When smaller veins branch off from the main ones and form a close, irregular network all through the blade, the leaf is *net-veined* (Fig. 230).

It is *parallel* or *straight-veined* if the veins run nearly parallel from the base to the point of the leaf or if parallel veins run from the midrib out to the margin. In neither of these last two cases do smaller veins join to form any network. (See Figures 231 and 232.)

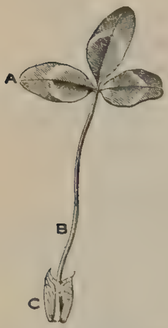


Fig. 226. A typical leaf. A, the blade; B, the petiole; C, the stipules

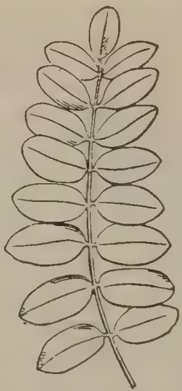


Fig. 227. A pinnately compound leaf

In the net-veined type of leaves there are two distinct forms: those in which the leaf shows several main veins radiating from the top of the petiole,—the *palmately net-veined* type (Fig. 233), like the maple; and those in which the leaf possesses one main midrib from base to apex, with smaller veins springing from both sides like the barbs of a feather, — the *pinnately net-veined* or *feather-veined* type, such as the elm or the beech. (See Figure 234.)

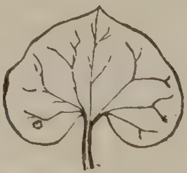


Fig. 228. A simple leaf

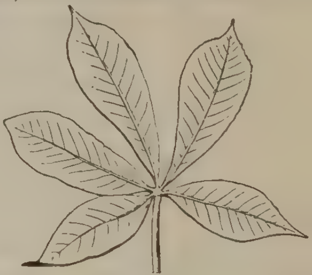


Fig. 229. A palmately compound leaf

Outline.—But it is in shape or outline that leaves show

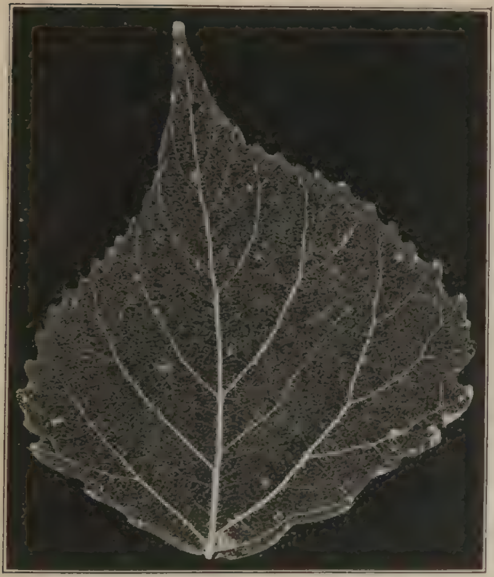


Fig. 230. A net-veined skeletonized leaf

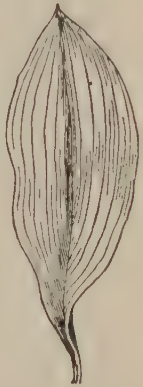


Fig. 231. A type of a parallel or straight-veined leaf

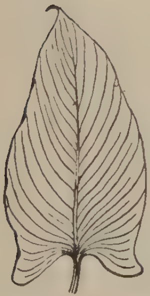


Fig. 232. Another type of parallel or straight veining

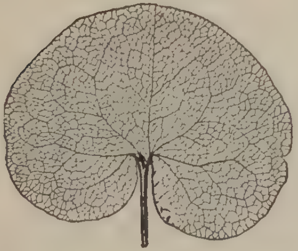


Fig. 233. A palmately net-veined leaf

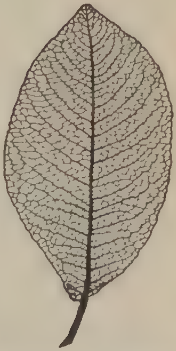


Fig. 234. A pinnately net-veined leaf

VENATION OF LEAVES

the greatest variety. In identifying and classifying plants it is very important to observe the outline of their leaves. A few of the most essential terms used in this connection are explained below:

Acicular, very narrow, stiff, and sharp-pointed, as in the pine (Fig. 225).

Linear, several times as long as broad and practically uniform in width (Fig. 235). This is not a common type.

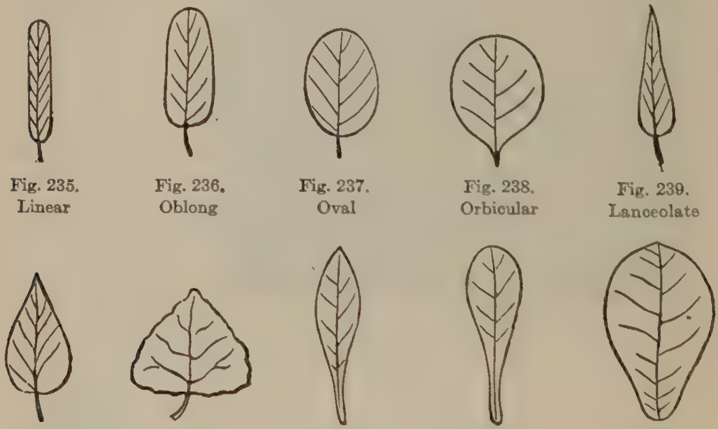


Fig. 235. Linear
Fig. 236. Oblong
Fig. 237. Oval
Fig. 238. Orbicular
Fig. 239. Lanceolate
Fig. 240. Ovate
Fig. 241. Deltoid
Fig. 242. Oblanceolate
Fig. 243. Spatulate
Fig. 244. Obovate

TYPES OF LEAF OUTLINES

Oblong, two or three times longer than broad with both ends alike or nearly so (Fig. 236).

Oval, somewhat longer than broad and similar at both ends (Fig. 237).

Orbicular, nearly circular in outline (Fig. 238).

Lanceolate, much longer than wide and tapering to a sharp point (Fig. 239).

Ovate, about twice as long as broad and narrow toward the apex (Fig. 240).

Deltoid, somewhat triangular and about as long as broad (Fig. 241).

Oblanceolate, like lanceolate, but reversed, broader at the top and tapering to the base (Fig. 242).

Spatulate, with a rounded apex and a long, narrow base (Fig. 243).

Obovate, resembling ovate reversed, narrowing to the base (Fig. 244).

These are distinct types, but many leaves have intermediate shapes and may be described by combining two terms, such as *linear-lanceolate, ovate-lanceolate, oblong-ovate*, etc.

Apex. — Botanical language has many terms to describe apices, bases, and margins.

The apex of a leaf may be:

Acuminate or *taper-pointed*, when tapering into a long narrow tip (Fig. 245).

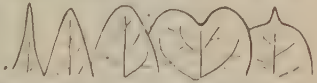


Fig. 245. Apices of leaves. From left to right—acuminate, acute, obtuse, obcordate, cuspidate

Acute, when the point of the leaf is an acute angle (Fig. 245).

Obtuse, when the point is an obtuse angle or rounded (Fig. 245).

Obcordate, when the top of the leaf has a fairly deep notch (Fig. 245).

Cuspidate, when the tip of the leaf ends in a distinct point (Fig. 245).

Base.—The base of a leaf may be any one of the following very distinct types:

Acute, when the base is an acute angle, as in the case of the apex.

Obtuse, when the base is an obtuse angle or rounded, as in the apex.

Tapering, when gradually narrowing down to the petiole.

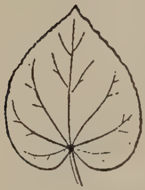


Fig. 246. Cordate

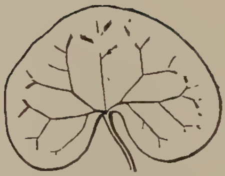


Fig. 247. Reniform

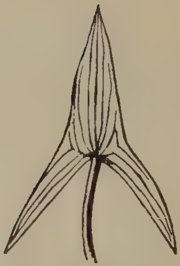


Fig. 248. Sagittate or arrow-shaped

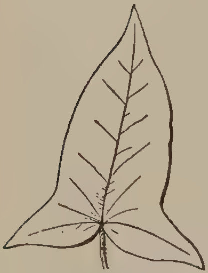


Fig. 249. Hastate or halberd-shaped

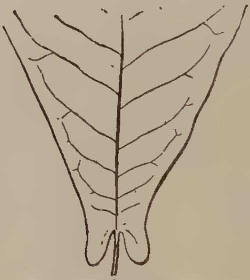


Fig. 250. Auriculate or ear-shaped

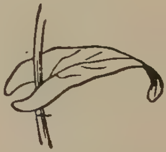


Fig. 251. Clasping

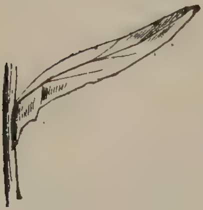


Fig. 252. Decurrent

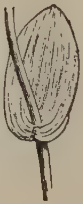


Fig. 253. Perfoliate

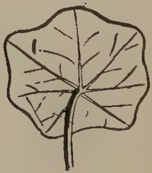


Fig. 254. Peltate

BASES OF LEAVES

Cordate, when the base has a distinct, sharp notch (Fig. 246).

Reniform, when the notch is rounded and broader (Fig. 247).

Sagittate or *arrow-shaped*, when the lobes at the base of the leaf are pointed downwards or backwards (Fig. 248).

Hastate or *halberd-shaped*, when the lobes are pointed outwards (Fig. 249).

Auriculate or *eared*, when it has a small, rounded, ear-like lobe on each side (Fig. 250), as in the New England aster.

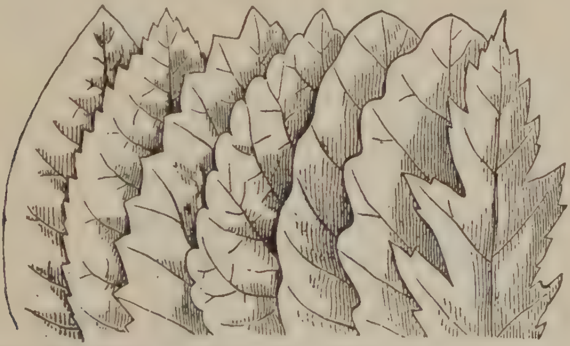


Fig. 255. Margins of leaves. From left to right—entire, serrate, dentate, crenate, wavy, sinuate or more strongly wavy, cut or jagged margins

Clasping, when the base of a sessile leaf is attached for some distance around the stem (Fig. 251).

Decurrent, when the leaf is sessile and the edges of the base continue for some distance down the stem (Fig. 252).

Perfoliate, when the stem seems to grow through the blade at the base (Fig. 253).

Peltate, when the petiole is attached to the under surface of the blade (Fig. 254).

Margin.—The following terms are used to describe the margins of leaves:

Entire, when the margin is quite regular or not indented in any way (Fig. 255).

Serrate, when it has saw-shaped teeth pointing forward toward the apex (Fig. 255).

Dentate, if the teeth point outwards (Fig. 255).

Crenate, if the teeth are rounded like scallops (Fig 255).

Sinuate, if the margin is wavy (Fig. 255).

Pinnatifid, when the edge of a pinnately net-veined leaf is deeply lobed (Fig. 256).

Palmatifid, when the margin of a palmately net-veined leaf is deeply lobed (Fig. 256).

Runcinate, when, in a pinnatifid leaf, the lobes are turned backwards and somewhat resemble claws. (See Figure 79.)

Multifid, when the margin is divided into many fine segments.

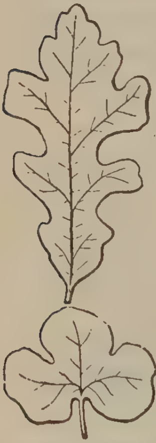


Fig. 256. Margins of leaves; above, pinnatifid; below, palmatifid

Surface. — The surfaces of leaves also present differences in nature of outgrowths. Some are *glabrous* or *smooth*; others are *glaucous*, that is covered with a bloom. They are *pubescent* when covered with usually fine short hairs, *spinous* or *prickly* when there are scattered spines over the surface, and *rugose* when the surface is creased or wrinkled.

Duration.—One other important respect in which leaves of plants differ is in the length of time that they remain attached to the plant and continue to perform their normal functions. Those that fall off the plant in the autumn are *deciduous*. Many of our common forest trees furnish examples of this type. Those that remain for a year or more are *persistent*. This group includes most of the evergreen trees. A few, particularly floral leaves, may drop early in the season. These are *fugacious* or *caducous*. The sepals of the common blood-root fall off almost as soon as the flower opens.

ROOTS

Roots may be classified according to origin, position, or form.

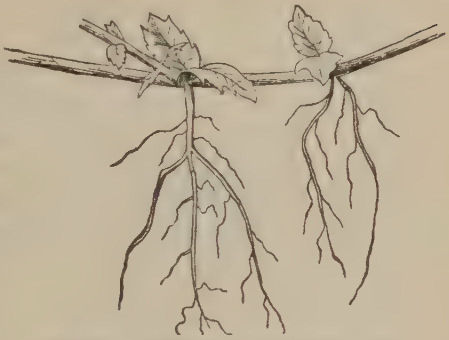


Fig. 257. Adventitious roots of the verbena

Origin.—A root that originates directly from the lower end of the hypocotyl in the seed is called a *primary* root. When branches are produced from it, these are known as *secondary* roots. Roots that grow from the stem or any part of the plant other than the lower end of the hypocotyl are called *adventitious*. (See Figure 257.) Examples of such roots are found in the English ivy, the poison ivy, the corn, and also in bulbs, corms, and cuttings.

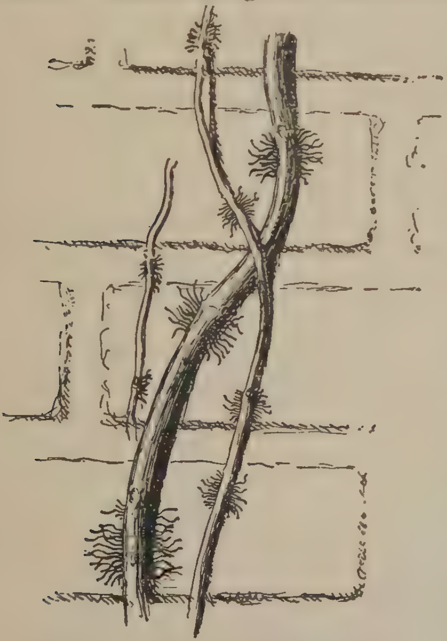


Fig. 258. Aerial roots of the trumpet creeper

Position. — When classed according to position, roots are subterranean, aerial, or aquatic. *Subterranean* roots are those which grow under ground. This class includes the roots of most of our plants. *Aerial* roots are those which grow in the air, such as the roots of the English ivy and the poison ivy. (See Figure 258.) *Aquatic* roots, such as the duckweed (*Lemna*), grow in water.

Form.—If the primary root is unbranched, or if the branches are distinctly smaller than the central axis, a *tap root*, such as we have seen in the wild mustard, is produced. If, however, the central axis is not well developed and the root is composed of many similar fibres, it is said to be *fibrous*, as in the aster.

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